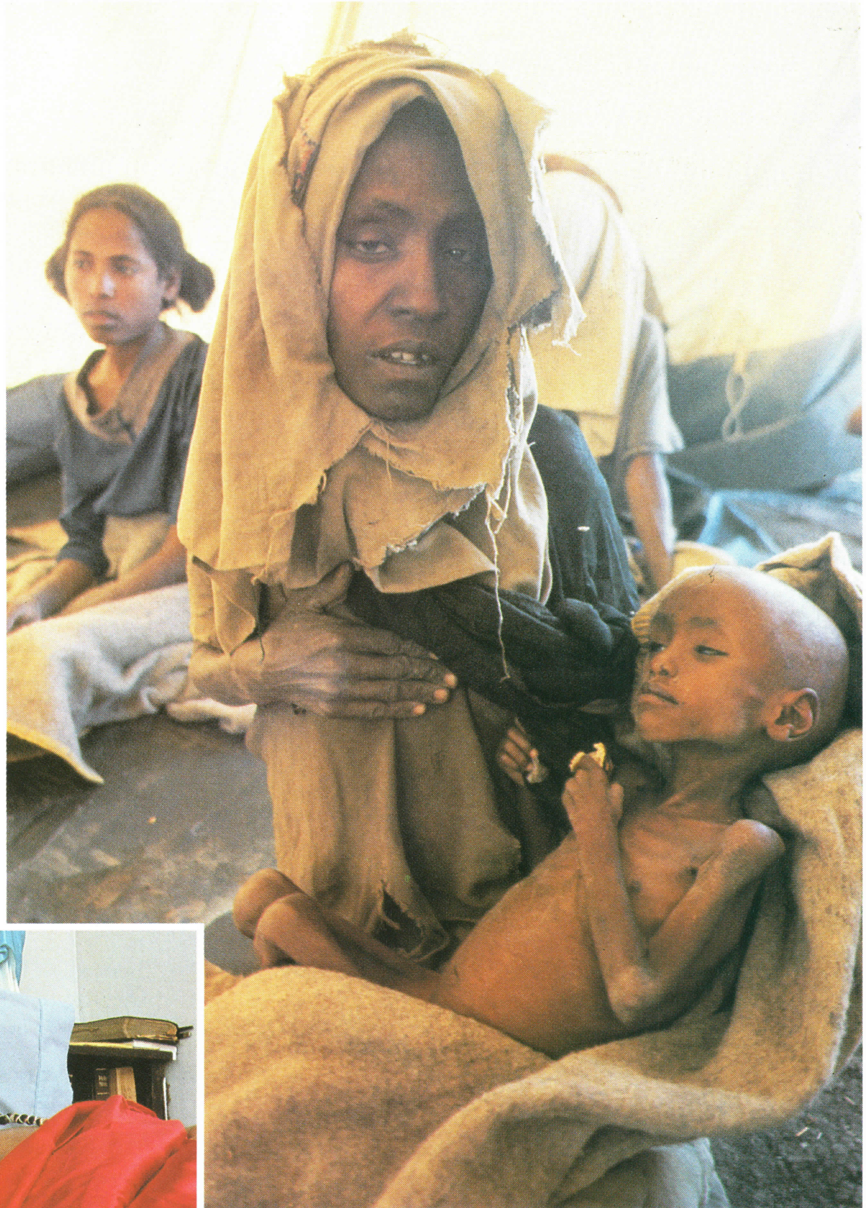
TIPPING THE BALANCE

- FOOD ABUSE
- ADDITIVES
- IMBALANCES



Rex Features

Weighing over 500 kg, *New York's fattest resident Walter Hudson has been unable to leave his bedroom for over 17 years. When he attempted to leave his house, he got stuck in the doorway. After that, he went on a diet of just 1,900 calories a day.*

Half the world's population *is under-nourished. By the year 2000, Africa, Asia and South America will need to provide double the amount of food they produce today, simply to maintain the present daily intake of their ever growing populations.*

IN 1980, 12 MILLION CHILDREN died of protein deficiency worldwide. The figures of famine make depressing reading. Yet on the other side of the coin affluent citizens of advanced countries are dying from obesity diseases.

Each year over half a million Americans and 180,000 Britons die from coronary artery disease, brought on by the build up of cholesterol and other fatty substances in their blood vessels. The average person in the western world consumes between 400 and 700 milligrams of cholesterol a day. The American Heart Association recommends a limit of no more than 300 milligrams a day. That is just 25 milligrams more than is contained in a medium-sized egg yolk.

Obesity through over-eating, especially of unhealthy foods, is associated with a large number of life-threatening conditions, including diabetes, high blood pressure, damage to vital organs and cancer. So while people in developed countries die of excessive amounts of food, others die of starvation.

Abuse of resources

The imbalance of world production and consumption often results in livestock being fed foodstuffs which could save the lives of large numbers of undernourished humans. Artificially high rice prices in the 1970s resulted in hundreds of thousands of deaths in Bangladesh. An increase in the demand for beef elsewhere in the world, coupled with poor maize and soya crops, caused western farmers to feed their herds with skimmed milk and wheat, while skimmed milk imports into under-developed countries suffering from famine were lacking.

Another misuse of protein sources can be seen in the fishing industry, where shoals of fish such as herring and mackerel have been decimated by ultra-modern fishing methods. In the past, fish were often processed into fish meals and added to livestock feeds – a process that has led to many intensively farmed chickens tasting fishy. In some cases the chickens have even been injected with chicken flavour to mask the fishy taste.

Problems of excess

A further example of imbalance is the problems faced in cultivating enough food in developing coun-


Gamma/Frank Spooner Pictures

Liposuction is a form of cosmetic surgery which involves liquifying excess fat, often around the thighs, then draining it off through vacuum tubes.

tries to feed even part of their populations while in the western world, problems result from producing too much food, including foods which need to be doctored with chemicals to make them acceptable to a public spoilt by choice.

We eat around 1.4 kilograms of artificial additives in our food every year. These include preservatives, anti-oxidants, stabilizers, emulsifiers, sweeteners, flavourings, bleaches, colours and water-retainers.

Preservatives keep foods bacteriologically safe and give them a longer shelf life. Some of the commonest preservatives used in meats are the nitrates and nitrites of sodium and potassium. These are effective against dangerous micro-organisms such as Clostridium botulinum, which causes botulism. These preservatives are also used to cure meats, such as bacon, and to give meat an attractive colour.

A chemical diet

Scientists are researching the possibility that nitrates can be converted into nitrites in the stomach. Nitrites can combine with amines to form nitrosamines, which have proved in animal tests to be carcinogenic (cancer producing). We also take in nitrates from vegetables that have been grown with the aid of nitrate fertilizers (which also find their way into some water supplies). Nitrates and nitrites are banned in baby foods because nitrites de-oxygenate the blood. They have also been linked to asthmatic reactions in some people. Nitrates and nitrites are found in sausages, ham, tinned meats and some cheeses.

Some bread still contains one of the propionic acid preservatives, used specifically to kill off moulds. Many people believe it can cause skin diseases and migraine headaches. As well as propionic acid in one form or other, a white sliced loaf could well contain ascorbic acid, a stabilizer to hold the bread mixture together, a dough conditioner such as azodicarbonamide to puff the bread up, and a bleach such as benzoyl peroxide. In addition bread may also contain residues of the pesticides, used to keep the grain unblemished.

Synthetic colour

The food industry relies heavily on added food colourings to improve a food's appearance. Some, such as the yellow colouring 'tartrazine', are believed to affect some people with allergic conditions, resulting in asthmatic reactions, and are best avoided by asthmatics and hyperactive children. Tartrazine is one of the commonest of all food colours and is derived from coal tar. Other synthetic colourings are: Sunset Yellow, Cochineal Red A, and Chocolate Brown HT.

HORROR BURGER

The burger bun is now most often made with unbleached flour, but contains invert sugar, dextrose and emulsifiers, which are made from glycerin, fatty acids and tartaric acid. It also has flour improvers that contain ascorbic acid, which occurs naturally in many fresh fruits, and potassium bromate – a bleaching agent that destroys vitamin E and can cause nausea, vomiting and severe abdominal pains.

The burger should contain only pure ground beef and a flavour enhancer (monosodium glutamate) to make it taste more appealing. But some contain a preservative, sodium metabisulphite – this can cause gastric irritation and also reduces the food's vitamin B content. It can also be dangerous for asthmatics.

The extras – the processed cheese, salad, relishes and dressing also contain more than you may have imagined. The cheese contains emulsifying salts and potassium bromate. The salad vegetables may contain traces of pesticides if they have not been washed properly. The ketchup and relishes contain preservatives and the mayonnaise contains edible gums, preservatives and a colouring agent. The chips that accompany your burger may well have been fried in animal fats.

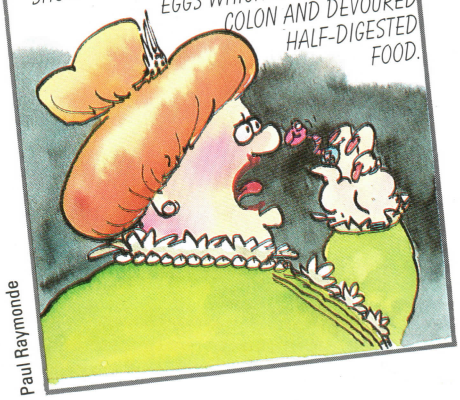
MEDICATED MEAT

Drugs administered to animals can remain in the meat after slaughter. The use of antibiotics as a cure-all in veterinary medicjne has been reponsible for causing allergic reactions in some people; furthermore, it could also lead to a resistant strain of bacteria. In the 1970s, doctors in Italy and Mexico noticed that small children were becoming sexually mature and that boys were developing breasts. In Italy this bizarre development was attributed to the growth-hormone diethylstilboestrol which had been injected into calves; in Mexico the cause was hormones fed to chickens. Hormone-fed meat is now illegal in EEC countries but is still sold in the USA.

Just amazing!

TAPEWORM DIET

FIGURE-CONSCIOUS VICTORIAN WOMEN FLOCKED TO TRY A NEW DIET PILL – HAILED AS A MIRACLE. ANALYSIS SHOWED THE PILLS TO BE TAPEWORM EGGS WHICH HATCHED IN THE COLON AND DEVOURED HALF-DIGESTED FOOD.


Paul Raymonde

THE TRAINED BODY

- MUSCLE POWER
- HEART POWER
- BRAIN POWER

HIGHER LEAPS, LONGER jumps, perfect 'ten' scores in gymnastics and less and less time taken to cover distances – these are all proof that the human body, when trained well enough, can stretch itself to ever newer limits.

It has been calculated that if all the muscles in the human body were laid together so that they all pulled in the same direction, enough force could be developed to lift a double-decker bus.

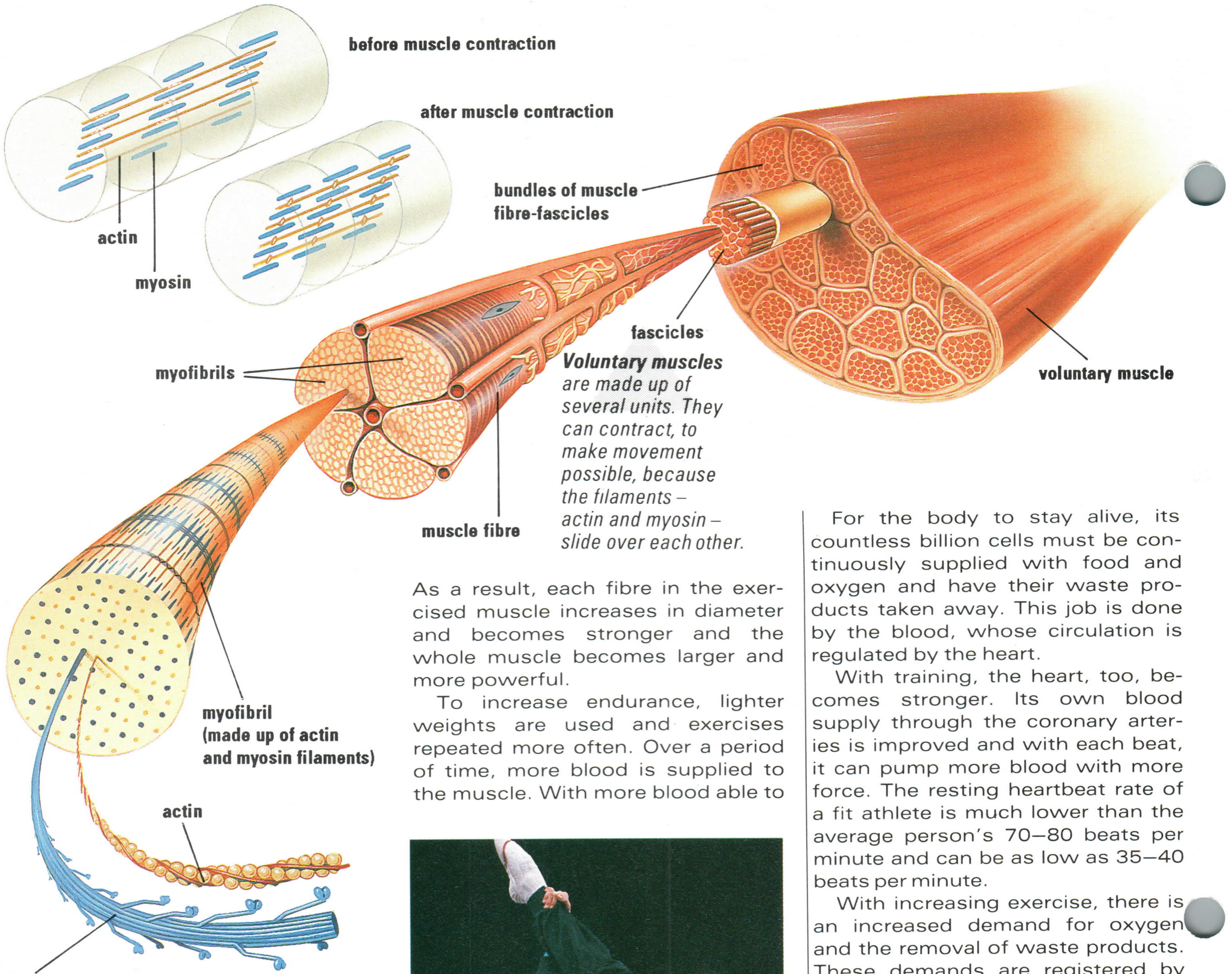
A special property of muscle lies in its ability to contract and produce force. A particular type of muscle transfers this force to bones where it is converted to movement by the many joints of the body. Joints must be tough enough to stop bones from coming apart under all

***Rippling muscles** can be developed by a woman as well as a man if she undertakes the right diet and training.*

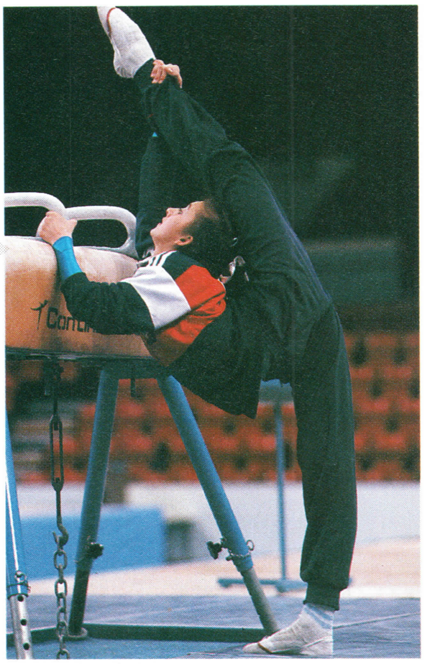
Colorsport

***The springboard** to success in all sport is a strong, well co-ordinated body – and dedication. To become a first class diver requires split second timing as well.*

Allsport/Bob Martin



Voluntary muscles *are made up of several units. They can contract, to make movement possible, because the filaments – actin and myosin – slide over each other.*



Hyper-extension: *the gymnast can stretch her body into unusual positions thanks to the strength and suppleness of her well-trained muscles.*

Supersport Photographs/Eileen Langsley

the stresses that the muscles put on them and flexible enough to allow smooth action.

Because these muscles are connected to the skeleton they are sometimes known as skeletal muscles. They are under the command of that part of the brain that we can control by our thoughts and are, therefore, called voluntary muscles. They are capable of fast, almost explosive, contraction. The forces that muscles can put on bones can sometimes be so great that they actually create stress fractures.

Pumping iron

To prepare the body for sport, it must be made used to new demands: more strength, more endurance, greater suppleness and better co-ordination.

Weight training and multi-gyms are used by many athletes to improve their muscular performance. Heavy weights are used to develop strength and exercises are repeated just a few times at each session. As a result, each fibre in the exercised muscle increases in diameter and becomes stronger and the whole muscle becomes larger and more powerful.

To increase endurance, lighter weights are used and exercises repeated more often. Over a period of time, more blood is supplied to the muscle. With more blood able to flow through the muscle, more food can be supplied to it to keep it working and, just as important, the waste products can be more efficiently removed from it.

In both sorts of training, it is thought that the sub-cellular powerhouses of the muscle cells – cigar-shaped bodies about 1/300 mm long, called mitochondria – increase in number. As a result, they can convert more glucose into ATP (adenosine triphosphate) which actually gives the cell the energy to contract. This process is called cellular 'respiration'.

For the body to stay alive, its countless billion cells must be continuously supplied with food and oxygen and have their waste products taken away. This job is done by the blood, whose circulation is regulated by the heart.

With training, the heart, too, becomes stronger. Its own blood supply through the coronary arteries is improved and with each beat, it can pump more blood with more force. The resting heartbeat rate of a fit athlete is much lower than the average person's 70–80 beats per minute and can be as low as 35–40 beats per minute.

With increasing exercise, there is an increased demand for oxygen and the removal of waste products. These demands are registered by the nervous system which stimulates changes within the heart and blood vessels. The increased heart rate and blood flow remove the waste more quickly and supply more oxygen and glucose to the muscles at the same time.

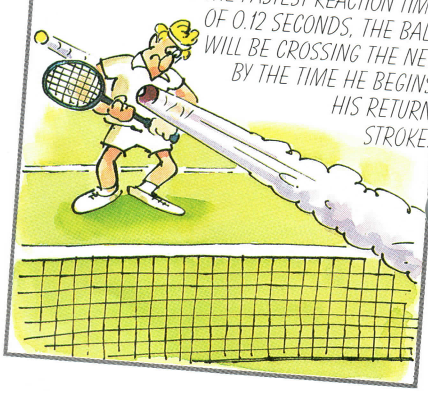
Co-ordination

Powerful muscles and a good circulation are necessities for successful athletes. But no matter how

Just amazing!

HIT AND MISS

BORIS BECKER'S SERVE PROBABLY TRAVELS AT AROUND 55 METRES PER SECOND. IF HIS OPPONENT HAS THE FASTEST REACTION TIME OF 0.12 SECONDS, THE BALL WILL BE CROSSING THE NET BY THE TIME HE BEGINS HIS RETURN STROKE.



Paul Raymonde

Mark Shearman

EATING TO WIN – MAXIMIZING ENERGY SUPPLIES

An important source of energy for the body is glycogen – the form in which carbohydrate is stored in the body. Scientists have found that if the body's level of glycogen is first completely run down, it can then be 'superloaded' to more than two or three times its original level.

Athletes who take part in endurance sports, such as running, cycling, swimming or hockey, need to build up a maximum reserve of energy for the competition. They do this by following a regime called glycogen supercompensation, or carbohydrate loading, for six days beforehand. Typically this consists of:

- **The depletion phase**
  DAY ONE:
  Training: to exhaustion to deplete glycogen in muscles
  Diet: normal

  DAYS TWO AND THREE:
  Training: light, to continue depletion of glycogen
  Diet: high in fat and protein, very low in starchy carbohydrate

- **The loading phase**
  DAYS FOUR, FIVE AND SIX:
  Training: very little or none
  Diet: build up carbohydrate intake. At least 70 per cent of total calories consumed must be from starchy carbohydrate: plenty of bread, pasta, cereals and potatoes.

- **The pre-competition meal**
  Easy to digest, high in carbohydrate, low in fat and protein (eg baked potato and cottage cheese; large green salad). Three glasses of liquid.

A modified version, without the high fat and protein diet of days two and three, recommends:

- **For three days before competition:**
  Training: reduced markedly.
  Diet: high in starchy carbohydrate.

fit the body is, if its various parts cannot act together at the athlete's will, very little activity, let alone sport, can be undertaken. The organ that co-ordinates the various parts of the body is the brain. This is where all decisions are taken.

As the tennis ball flies towards the player, the eyes note its swift passage and send messages via the sensory nerves to the brain. Here, the message is decoded and interpreted as sight. Most of the delay in response, what we call reaction time, is really the brain deciding what to do. All options must be calculated with speed and accuracy if the ball is to be returned.

Perfect response

The body's response is a whole-body response. It is not just the racket arm that must be swung to meet the ball hurtling towards it. The feet must be in the right place, the balance must be right and already the brain must be calculating where next to move if the ball comes back again from the server.

The part of the brain that does the co-ordinating of this whole-body effort is the cerebellum, a branching, tree-like part of the brain situated near where the spinal cord swells out to form the brain itself.

It is normally regarded as a 'lower' part of the brain because it is not directly under the control of conscious 'will'. However, without it, even relatively simple actions, such as lifting a cup to the mouth and drinking from it, would be virtually impossible. It is the cerebellum that takes in all the little bits of information about what is a successful movement and what is not and puts it all together for us as a 'package' of movement instructions. Practice and training educate the cerebellum.

Balancing act

Shut your eyes. Think about your body. Where are your feet? Your arms and hands?

All the body's skeletal mucles have sensory nerve endings in them called stretch receptors. These stretch receptors detect continuously how extended or contracted each muscle is. From all this information that it receives, the brain works out the configuration of the body at each movement.

When the information from these sensors is interrupted (as happens when a pain-killing injection is given or when the blood supply is restricted, giving the sensation of 'pins and needles') the brain cannot sense the affected parts.

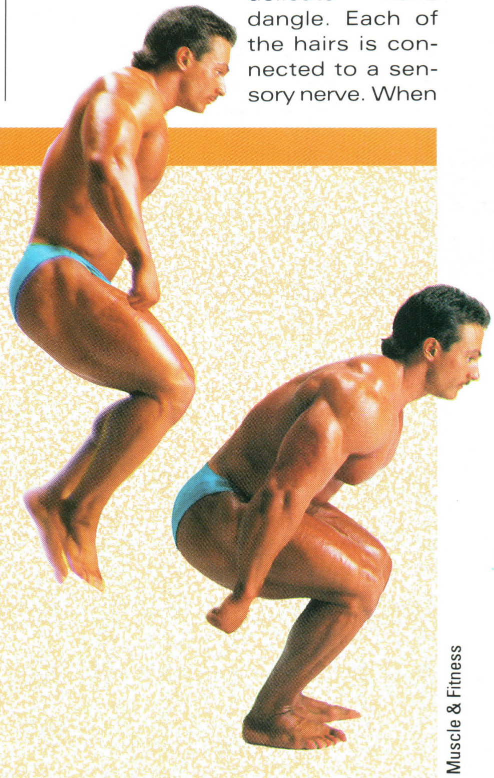
In addition to this body-shape information, the brain also works out which way up the body is and if it is tilting or not by using two sets of balance organs which are situated on the sides of the head, one behind each ear. Each consists of three fluid-filled canals, into which delicate hairs dangle. Each of the hairs is connected to a sensory nerve. When

THE HIT METHOD

This technique is designed to develop explosive strength and speed – it is mainly used by sprinters and jumpers. The idea is to hit a fixed, resilient surface with the feet and bounce off it. The athlete stands on a raised platform; steps off, lands on both feet, then leaps as high as 75–100 cm into the air. A leap to 75 cm builds up speed; to 100 cm, strength.

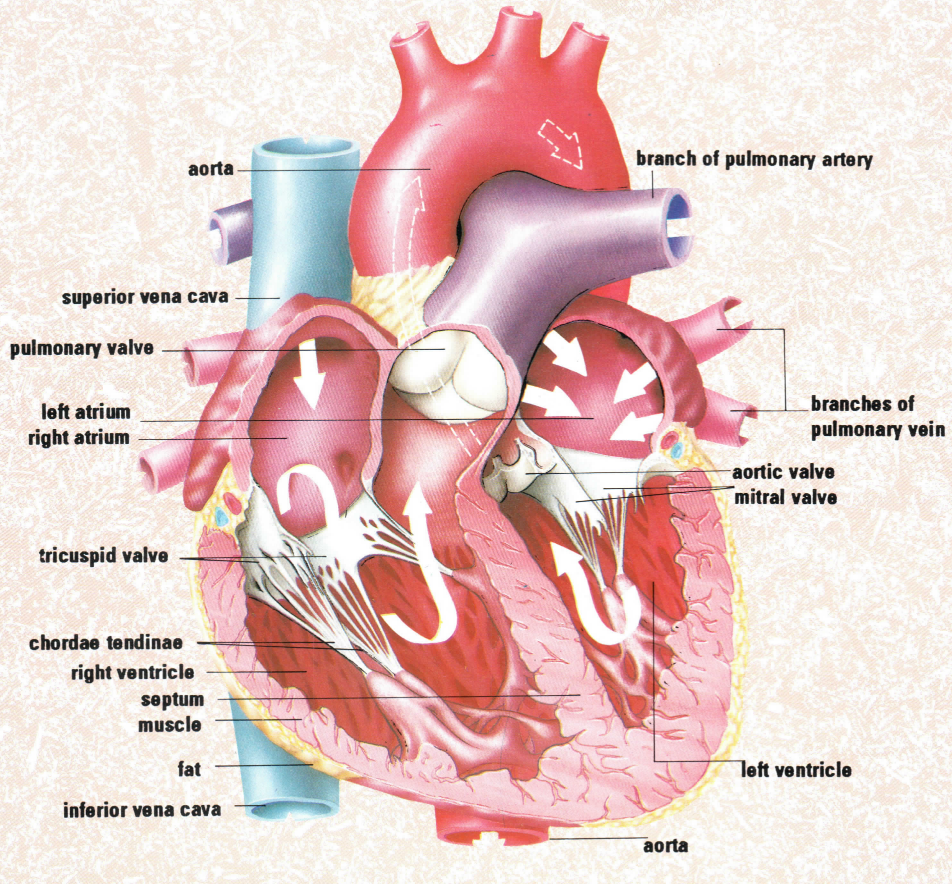
In the USSR, swings and sledges are also used. As the seated athlete comes forward on the downward swing, he pushes off against a platform with maximum force and swings back. In the sled, he slides down an incline, meets a wall with his feet and pushes off it back up the incline.

The hit method is *only* suitable for trained athletes who are already very fit and strong and must only be carried out under careful supervision as it is a potentially highly dangerous technique.



Muscle & Fitness

THE ATHLETE'S HEART: AN EFFICIENT PUMPING MUSCLE



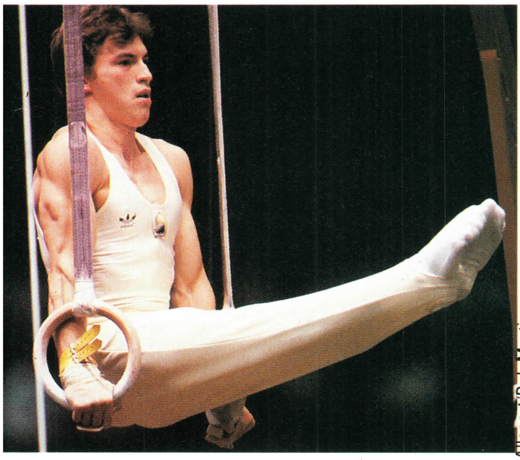
arrows show blood flow through the heart

Just like any other muscle, the heart will respond to a specific training programme. Unlike skeletal muscles, the heart is an involuntary muscle, pumping blood and keeping it flowing throughout the body. The adult human body contains 5 litres of blood.

- the amount of blood pumped by the heart of an average person is 5–6 litres per minute
- in highly trained endurance athletes, it can be 40 litres per minute
- the number of times the heart beats – the pulse – in an average person is 70–80 per minute
- the athlete's pulse can be as low as 35 per minute

Aerobic training, such as running or swimming, has several beneficial effects on the heart.

- it can make the heart more efficient: more blood is pumped per beat
- during exercise, more blood goes to the exercising muscles and less to the non-essential areas
- the size of the heart may increase



Allsport/Bob Martin

***Jack-knifed in mid-air** – the gymnast requires incredibly strong abdominal muscles to maintain this position for the required two seconds.*

ever the fluid is set moving in relation to the hair, the hair bends and a message is sent to the brain.

The three canals are all connected to a sac-like structure – the sacculus – that tells the brain which direction is down. It is when this part of the balance organ gets confused that we get that funny feeling in the stomach, as when a lift suddenly starts to descend.

No sport better combines muscle flexibility and balanced co-ordination than gymnastics: the brain has to work like a turbo-charged computer to take in all the information from stretch receptors and balance organs so that the gymnast lands on his or her feet, and does not fall off the narrow beam, bars or 'horse'.

Maximizing momentum

Karate is probably one of the best-known martial arts. The force of the karate blow depends mainly on two things: the speed of the part of the body being used just before impact (velocity) and its weight (mass). By multiplying velocity by mass a measure called momentum is obtained. The higher the momentum of a body, the more force it is able to exert. So a light-weight travelling fast can deliver the same amount of force as a heavy-weight travelling more slowly.

The skill of karate lies in making the punch as fast as possible and in making the effective weight as great as possible.

The same principles are at work in boxing, but the range of blows that are allowed is less. The classic position is sideways, with the trailing leg ready to brace the body forward so that the whole weight of the body can go into the punch.

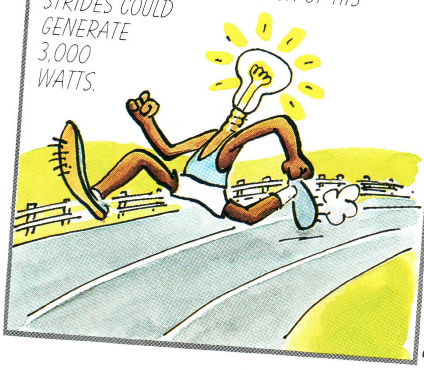
Another important difference between karate and boxing is, of course, that boxers wear gloves which are packed with stuffing.

A very important aspect of the destructive power of a punch is the time it takes to transfer its momentum to the opponent. The quicker the change of momentum, the greater the force. A punch that delivers its momentum in one-tenth of a second would have twice the force if it did the same in half the time.

Just amazing!

STREAK LIGHTNING

WHEN US OLYMPIC RUNNER CARL LEWIS COMPETES FOR THE 100 METRES, IT HAS BEEN CALCULATED THAT EACH OF HIS STRIDES COULD GENERATE 3,000 WATTS.



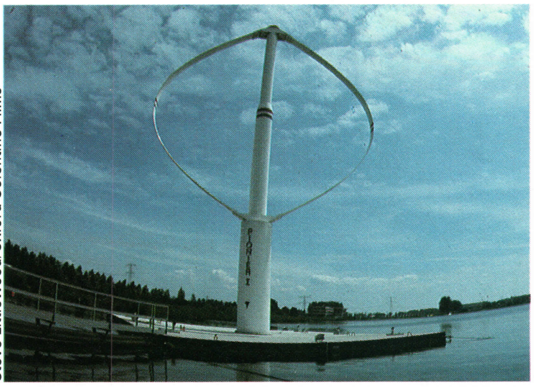
Paul Raymonde

Kim Westerskov/Oxford Scientific Films

***Photovoltaic cells** convert light into electricity; this means they can be used in very cold climates – even in the Antarctic. The electricity produced is stored in batteries.*

- WIND TURBINES
- WING SAILS
- PHOTOVOLTAICS

DURING THE 1970s, THE PRICE of oil shot up on two occasions. This generated a lot of interest in renewable forms of energy not involving expensive fossil fuels, such as coal and oil.



Steve Littlewood/Oxford Scientific Films

***Vertical wind turbines** are still experimental. Unlike horizontal wind turbines, they do not have to be turned into the wind in order to operate at maximum efficiency. This makes the construction of vertical turbines much simpler.*

NATURAL POWER

Tim Davis/SPL

***Wind farms** consist of hundreds of small wind turbines. Together the machines generate enough electricity to be economic, but because so many are needed, the farms can only be built in places with land to spare.*

All these energy sources – wind, sunshine, waves, bio-energy – are ways of capturing the enormous amount of energy poured on to the Earth's surface by the Sun. The most direct way of doing this is to harness the wind. Highly efficient modern windmills are already being used for generating electricity on the Orkney Islands and in other small communities too remote to receive normal electricity supplies. In this type of situation, the high cost of building the windmill is balanced by the convenience of electrical power.

The biggest windmills look like giant aircraft propeller blades and are known as horizontal wind turbines. When the wind hits the blades, they revolve and drive an

***Wing sails** are computer-controlled to make the most of the wind. But ships are still fitted with engines so their speed can be maintained when there is no wind.*

Walker Wingsail Systems

***Walker wing sails** have a tear-drop cross section to maximize power and minimize drag. Sails and computer software are tailored to each ship for maximum efficiency.*

***Solar panels**, such as these, consist of aluminium slats that absorb the heat of the Sun, and small bore pipes through which water circulates. Small panels are sometimes used to heat water for the home, but large installations are more successful. These are generally used for heating buildings and swimming pools.*

Sebart/Jerrican

electric generator, which is usually connected straight on to the main propeller shaft.

By the 1990s the total amount of electrical power generated world-wide by wind was about 1,500 megawatts – almost all of it in California, in the USA, where the tax system encourages this form of generation. This is about one and a half times the output of a single, large, coal-powered, electricity generating station. About ten per cent of world electricity output could be generated using wind power but, so far, the cost is too high to make it worthwhile.

Wind farms

Wind power is very attractive because it is one of the very few energy sources that is genuinely pollution-free. On the other hand, large wind farms sited on the coast would ruin the scenery and fill the countryside with a loud swooshing sound.

Far out to sea, the wind blows strongly almost every day, so the supply of wind power should be quite reliable. To take advantage of this, there are proposals to build floating platforms carrying several large wind turbines driving electrical generators. However, transmitting the power back to the land is a major problem at present.

High altitude winds or jet streams are harnessed by pilots making flights from west to east. By careful planning, they can make faster crossings and use less fuel simply by cruising at the jet stream altitude.

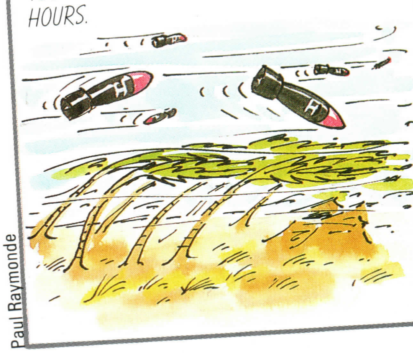
The heat of the Sun can be used directly by designing buildings with plenty of insulation and large windows on the side that faces the Sun. The windows are glazed with 'low emissivity glass' that lets the Sun's rays into the building but prevents heat escaping. This is the same principle as the greenhouse, which has been a way of exploiting the Sun's heat for centuries.

The Sun can also be used to heat water using solar panels. These are elaborate heat-exchangers, often fitted on roofs as part of the domestic hot water system, to substitute an ordinary boiler.

Just amazing!

NATURE'S H-BOMB

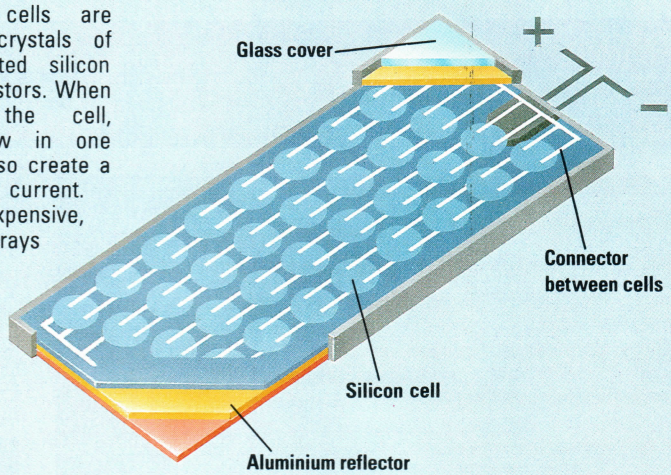
A FULLY-DEVELOPED HURRICANE PUMPS 2 MILLION TONS OF AIR PER SECOND UP INTO THE EYE OF THE STORM AND OUT AGAIN, RELEASING ENERGY EQUAL TO 400 HYDROGEN BOMBS EVERY 24 HOURS.



Paul Raymonde

ELECTRICITY FROM SUNLIGHT

Photovoltaic cells are made from crystals of specially treated silicon just like transistors. When light hits the cell, electrons flow in one direction and so create a small electric current. Although expensive, photovoltaic arrays last for up to 20 years without any need for maintenance.



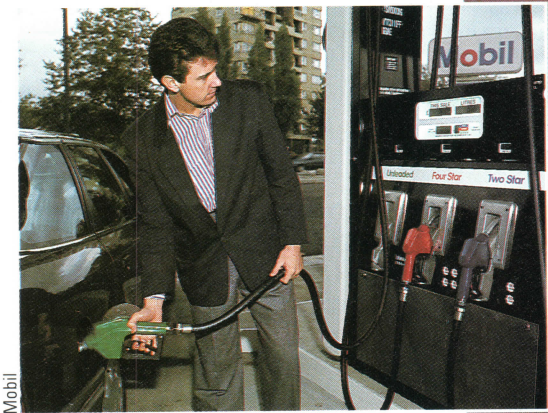
FUELS OF THE FUTURE

- OIL FUEL PRODUCTS
- PETROL POLLUTION
- CLEANER FUELS

WASTE FROM CHICKENS and other animals may provide the fuel of the future. Bacteria can change these wastes into a gas mixture rich in methane, which can be used instead of petrol. The use of methane would avoid a fuel crisis when oil supplies dwindle and would cause much less pollution than petrol.

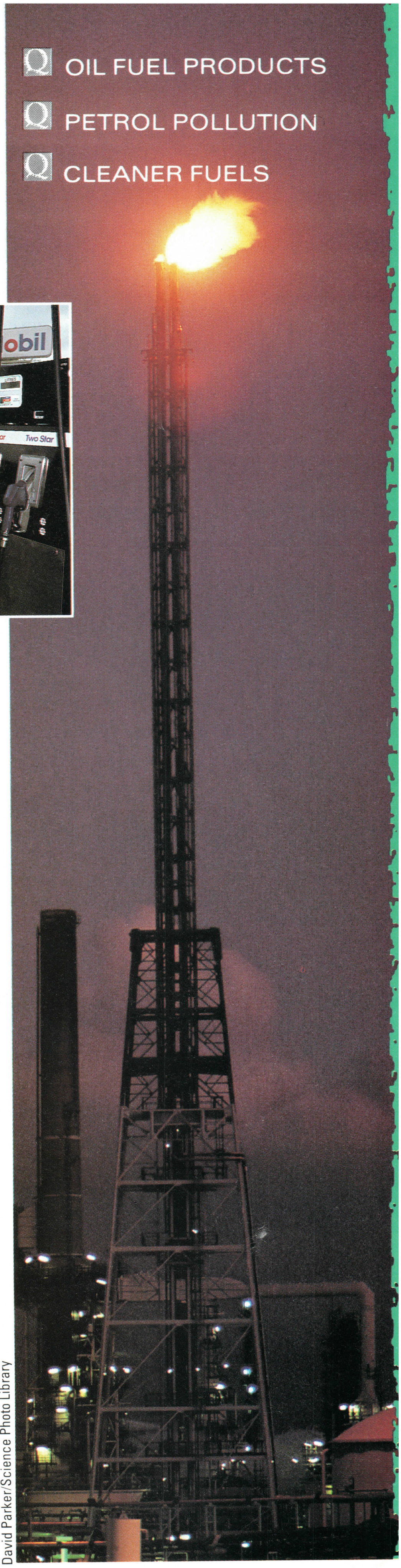
Oil refineries produce a large range of chemicals, including many fuels. These include fuel oil, diesel oil, kerosene, petrol and petroleum gases. Diesel fuel is becoming increasingly popular for road vehicles because it is cheaper to produce than petrol. Also, it has the great advantage that it does not have lead added to it – lead causes pollution.

Lead compounds are added to ordinary petrol to improve its octane rating – a measure of how smoothly it burns. This helps to avoid violent explosions (called knocking) in the engine. Lead also helps to lubricate the engine pistons. New laws say that, to reduce lead pollution, unleaded petrol must be generally available in Europe from October 1989, so alternative anti-knock additives will probably be needed.



Mobil

Unleaded petrol *for greatly reduced pollution is dispensed through a nozzle that is colour-coded green.*



Waste gas *is burnt off at an oil refinery, where fuels and other petroleum products are obtained from crude oil.*

David Parker/Science Photo Library

Fighting pollution

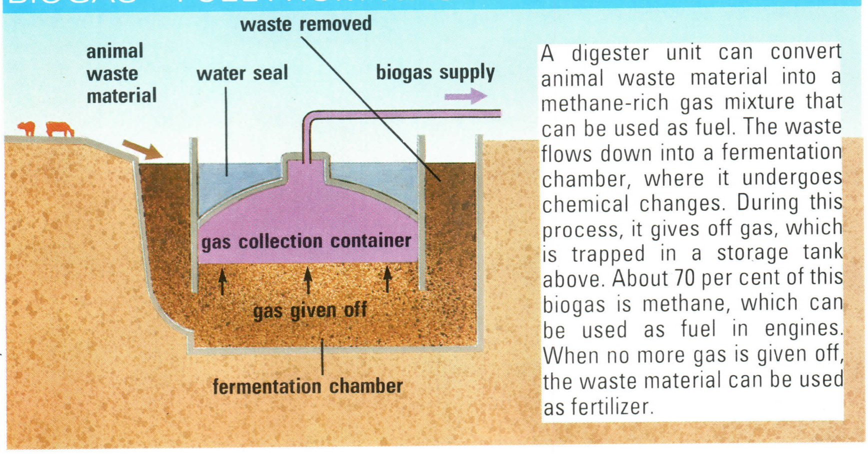
Petrol engines produce several kinds of pollution when the petrol-air mixture ignites. The lead-containing compounds produced can build up in human nervous tissues and in the brain, and may affect intelligence – especially in the unborn and in growing children.

Sunlight acts on the oxides of nitrogen formed to produce smog. This consists of compounds that irritate the nose and throat and can sometimes kill. Carbon monoxide is much more dangerous. Even a small amount leaking from a defective exhaust system into a car can cause illness or death.

Ozone is another harmful gas produced by petrol engines. High in the atmosphere, ozone screens out harmful ultraviolet radiation in sunlight. But it is no good to us at ground level. It is poisonous and may also help to cause harmful acid rain.

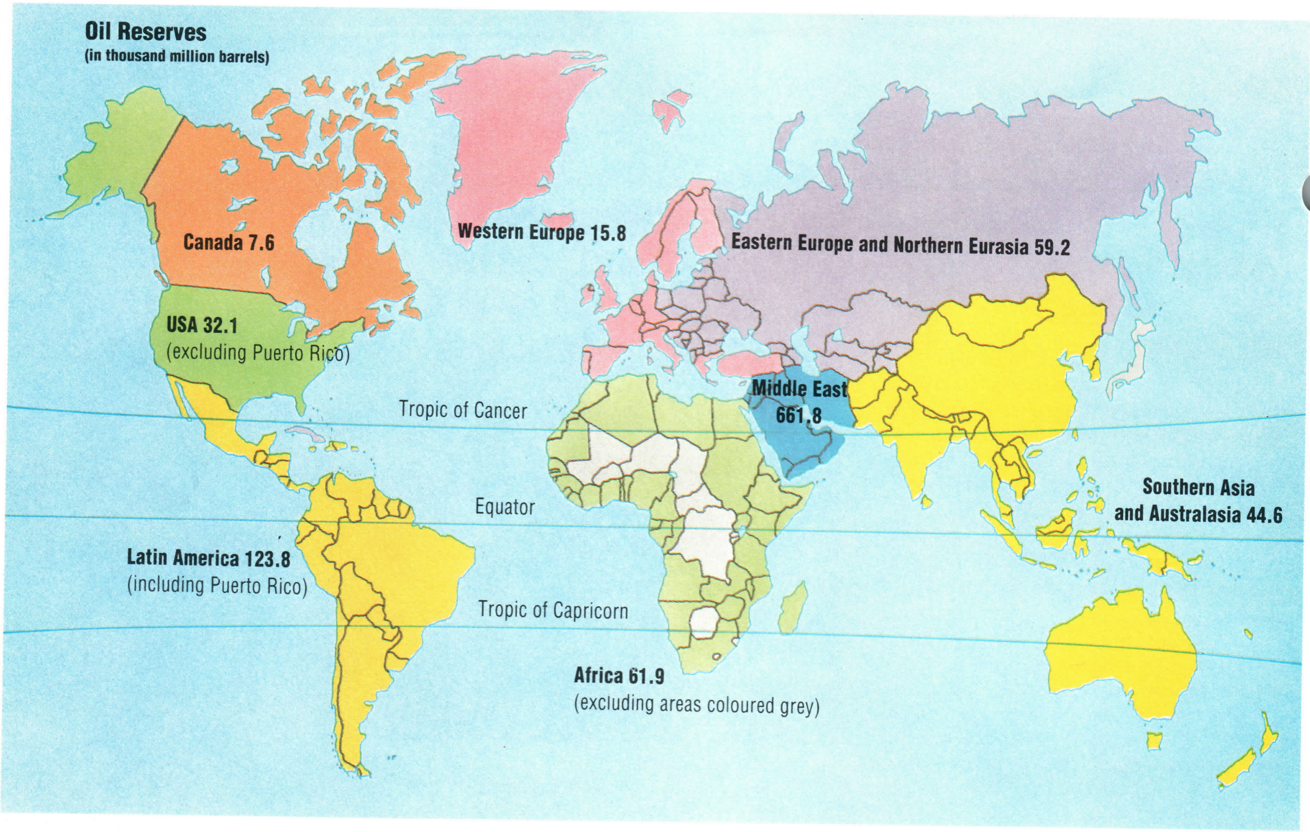
One way of tackling lead pollution

BIOGAS – FUEL FROM WASTE



A digester unit can convert animal waste material into a methane-rich gas mixture that can be used as fuel. The waste flows down into a fermentation chamber, where it undergoes chemical changes. During this process, it gives off gas, which is trapped in a storage tank above. About 70 per cent of this biogas is methane, which can be used as fuel in engines. When no more gas is given off, the waste material can be used as fertilizer.

Janos Marffy



Mark Franklin

__The Middle East,__ although a relatively small area, is a major oil producing region possessing over 60 per cent of the world's oil reserves.

is to develop lean-burn engines, in which less fuel is mixed with a given quantity of air. The fuel is burnt more efficiently and at a lower temperature. This reduces fuel consumption, and the exhaust contains far less lead and other polluting materials.

The European Community, following the United States' lead, requires all new vehicle engines to become cleaner during the 1990s. In the near future, expensive devices called catalytic converters will be needed to remove harmful substances from exhaust fumes in order to comply with the new laws. The authorities are also insisting that lead-free petrol be put on sale in all its member countries.

In 1973 oil prices soared. Poor countries were especially hard hit. One of them, Brazil, reacted by promoting a new fuel for its cars – alcohol made from sugar-cane juice. The alcohol was ethanol, or ethyl alcohol, produced by the fermentation of cane sugar. It was either blended with petrol or used 'neat'. Two million cars have been converted to run on pure ethanol.

__Brazil's sugar cane__ crop is now providing some fuel for cars. Yeast converts the sugary juice from the cane into ethyl alcohol, which can be used in engines as a substitute for petrol.

Hutchinson Library

Other vegetable crops have been used as motor fuels before. Vegetable oils were used in the first diesel engines. Now they're being experimented with again as a possible source of cheap fuels in the Third World.

Running on gas

Engines can be run on methane gas. One source of this is waste from chickens and other animals. The wastes are broken down by bacteria in airtight containers to form a 'biogas' that is typically 70 per cent methane and 30 per cent carbon dioxide.

Even more appealing is the possibility of getting fuel from water. When an electric current is passed through it, water splits up into hydrogen and oxygen gases. The hydrogen could be used to fuel vehicles, and the only waste product would be water vapour.

Another alternative to oil is synthetic liquid fuel, which is generally known as synfuel. Coal can be liquefied by adding hydrogen gas to it at a high temperature and pressure. Tar sands and oil shales can also be processed to produce synfuels. All these sources of fuels may provide some insurance when oil becomes too expensive.

Just amazing!

SLICK FUEL

ONE AMERICAN UNIVERSITY RUNS ITS BUSES ON USED COOKING OIL, SUITABLY FILTERED BEFOREHAND TO REMOVE BITS OF FOOD.

Paul Raymonde

PEDAL POWER

- ALUMINIUM FRAMES
- SOLID WHEELS
- COGGED BELTS

Tony Stone Photo Library, London

Photosport International

***BMX bikes** have small wheels and straight forks for fast steering responses. Saddles are low and set right over the back wheel for good balance. Road racers (inset left) sit further forward and with the head down for lower wind resistance. The small front wheel, dropped handle-bars and solid wheels also help the aerodynamics.*

BICYCLES ARE ONE OF THE cheapest forms of mechanical transport. The traditional 'sit up and beg' machine gives freedom from footslogging to European schoolboys, African peasants and millions of other people around the world.

The average adult cyclist produces about one eighth of a horsepower, which can easily propel a cyclist at 15 km/h. Most people are comfortable turning the pedals at about 60 or 70 revolutions per minute. For maximum efficiency and speeds above 15 km/h, bikes need gearing systems that allow the rider to keep pedalling at this number of revolutions, whether he or she is going slowly up hill or speeding on a level road.

Steel is the traditional material for bike frames and components because it is strong and fairly cheap. Steel tubes are assembled into bike frames using steel joining pieces known as lugs. Molten brass is used to fix the tubes in the lugs and when the tubes are assembled into the traditional double-diamond shape, bike frames are surprisingly light and rigid. The process of joining the tubes with molten brass is known as brazing.

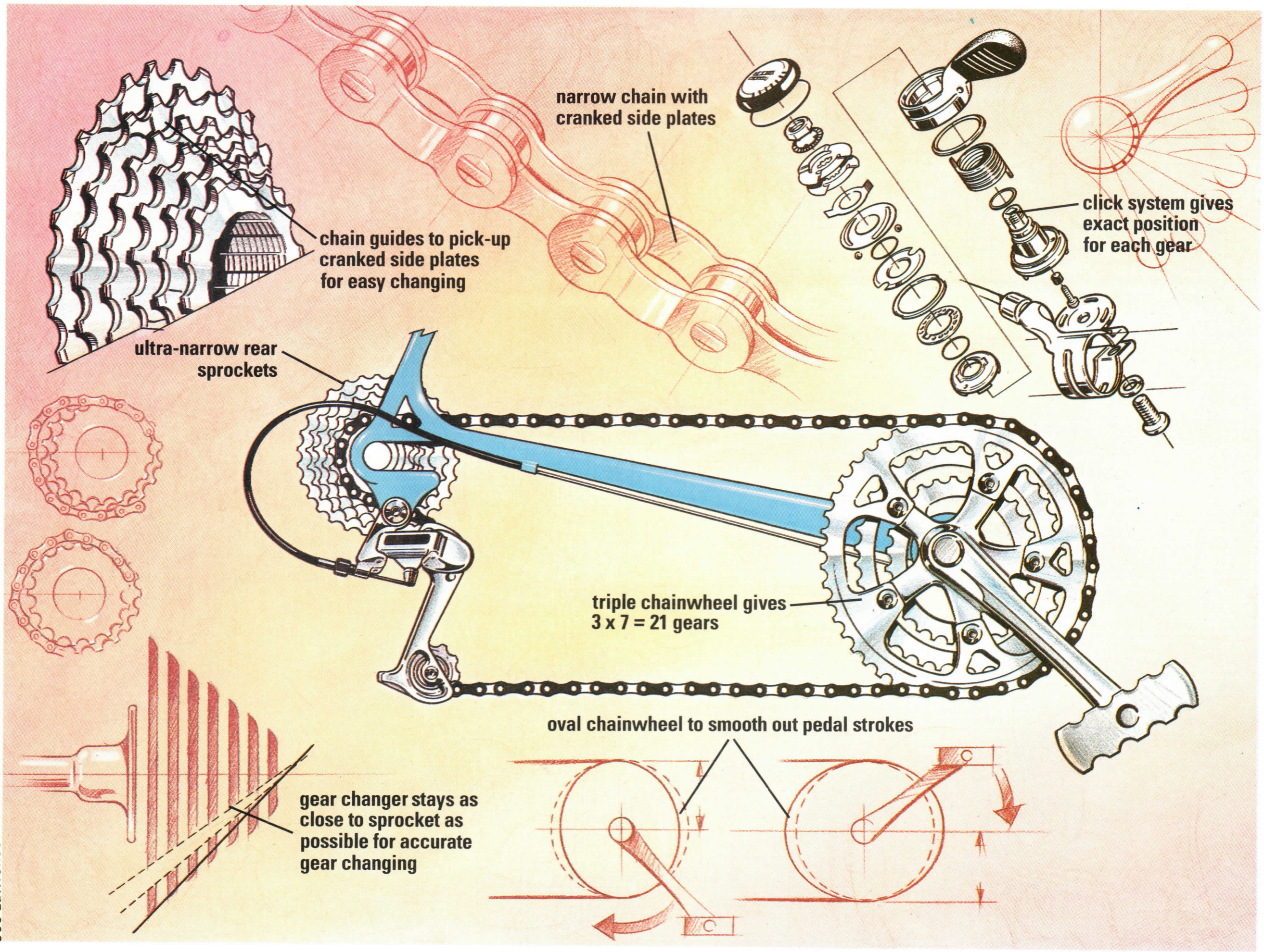
Stronger alloy steels are constantly being developed, which allows bike manufacturers to use thinner and therefore lighter tubing. Unfortunately, this puts up the cost and multiplies production problems because the alloy content of the steel can easily be destroyed if the steel is overheated during the brazing process.

To get round this problem and to make bikes lighter and more aerodynamic, an ever-expanding range of materials is now being used. These materials include:

- light aluminium alloys for frames
- titanium to replace steel for components like brakes, gears and pedals
- composite plastics for frames and wheels
- moulded plastics for saddles, wheels and fairings
- carbon fibre for wheel rims.

Tony Stone Photo Library, London

***In China**, bikes are a cheap and popular form of transport. Cyclists are separated from the rest of the traffic to ensure that buses and official cars can get through. Enormous cycle parks are dotted throughout Chinese towns.*



Joe Lawrence

Nevertheless, for the moment, most sports and racing bikes are still made from steel, though the best ones now have aerodynamic tear-drop shaped tubes. These absorb less energy as they move through the air but are difficult to manufacture. There are also more aluminium frames being built as manufacturers find better ways to join the tubes together into frames.

When aluminium was first used for bike frames, engineering adhesives and metal pegs were used to fasten the tubes together; but now that low-temperature aluminium welding has been developed, the joints can be welded. However, all welding and brazing processes tend to weaken the metal, while adhesives are difficult to use for mass production. To get round this, aluminium frames are now in large scale production using separate lugs to join the tubes in the same way as traditional steel frames. During assembly, the frame tubes are forced on to the lugs using

Derailleur gears *for Mountain bikes have up to 21 gears to cope with the hills. Each of the three chainwheels can be used with each of the seven sprockets on the back wheel, making 21 gears in total. In the heat of the action, gear changes must be smooth and accurate, so the chain links and the sprockets are specially shaped to work together.*

Raleigh Ltd

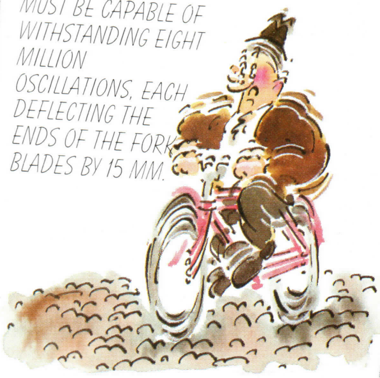
Cannondale Corporation

Moulded plastic *wheels are fitted to some BMXs to save spoke breakages on touchdown. Sports bikes (right) with frames made from aerodynamic aluminium tubes keep the traditional shape.*

Just amazing!

SHAKE IT ALL OVER

THE FRONT FORK IS THE MOST HIGHLY STRESSED COMPONENT OF A BICYCLE FRAME. IN TESTS IT MUST BE CAPABLE OF WITHSTANDING EIGHT MILLION OSCILLATIONS, EACH DEFLECTING THE ENDS OF THE FORK BLADES BY 15 MM.



Paul Raymonde

PEDAL POWER

Cannondale Corporation

Strida Ltd

Folding bikes *are fitted with small wheels to make them easier to handle and store. Small wheels do not smooth out bumps in the road, so thick, wide tyres are fitted to improve the ride. Unfortunately this increases 'rolling resistance' – a force caused by wheel distortion and opposing forward motion.*

Cycles Peugeot

Aluminium frames *have large radius welds, so the stresses on the joints are spread over a large area of the tubes. Weldless aluminium frames (left) have joints called lugs – the tubes are a tight fit on the lugs so they never come apart.*

hydraulic pressure only, applied by specially designed machines.

Composite materials and lightweight titanium metal were first used by cycle designers when building racing bikes to break the Hour Record — the number of kilometres that can be packed into an hour's continuous riding. These Hour Record bikes were far too uncomfortable for normal purposes, but they did free designers from their fixed ideas about the shape of bicycles.

Many of these new shape frames and solid wheels can only be made using resin composites reinforced by high-strength fibres such as Kevlar and carbon fibre. These materials allow stiff and strong bike frames to be made in a much wider variety of designs. They are also resilient and springy, which makes them ideal for Mountain bikes and BMXs.

Town bikes

During the late 1980s, the Mountain bike with 18-speed or 21-speed gearing became very popular. But the main design feature is that the rider sits bolt upright, so aerodynamic efficiency is inevitably very poor. Nevertheless Mountain bikes are popular in town as well as country, especially among bike messengers, because they can be ridden up and down kerbs and are very comfortable for short journeys.

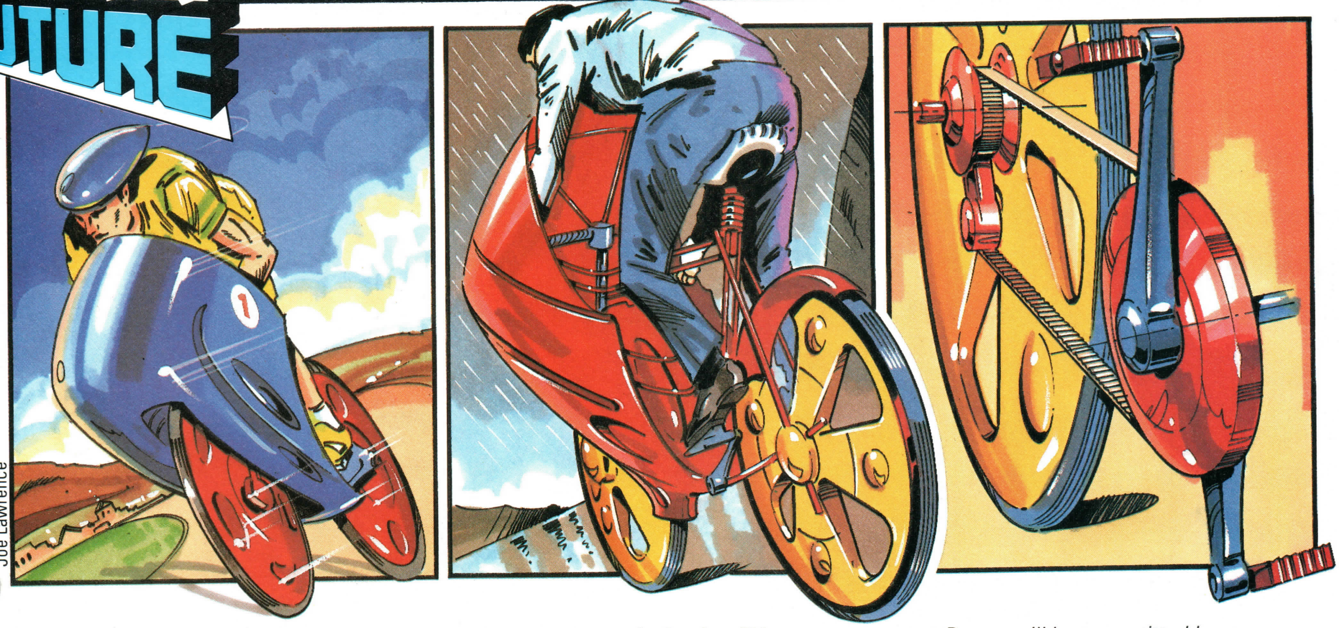
The latest folding bikes have a frame made of aluminium, which gives a comfortable ride because it does not transmit shock in the way that steel does.

The biggest step forward so far as most people are concerned is that the messy chain has been replaced with a maintenance-free cogged rubber belt. Work is going on to develop a hub gearing system for use with a belt drive.

Bicycles are such an efficient user of energy that in some towns of East Asia, basic passenger transport depends on cycle rickshaws, or tri-shaws. Two passengers sit over the twin front wheels of the tri-shaw and the whole thing is propelled by the one eighth of a horsepower produced by the tri-shaw operator.

INTO THE FUTURE

ROUGH TERRAIN VEHICLES



Joe Lawrence

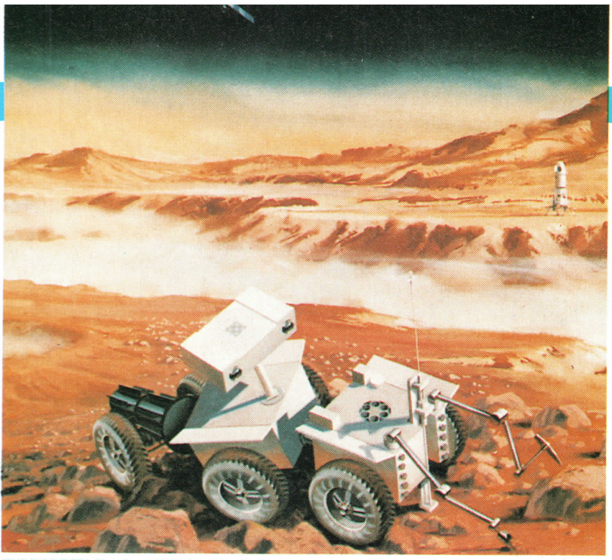
▲ *Streamlined bicycles will raise the average rider's speed from 24 km/h to 40 km/h, while racing cyclists will average 64 km/h for up to seven hours.*

▲ *The fairing and wheels will be supported by a network of narrow tubes. Behind the fairing, the rider stays warm and dry whatever the weather.*

▲ *Power will be transmitted by a maintenance-free rubber belt. The gearing system will be stepless, using expanding pulleys and hydraulic control.*

BHC/Westland Aerospace

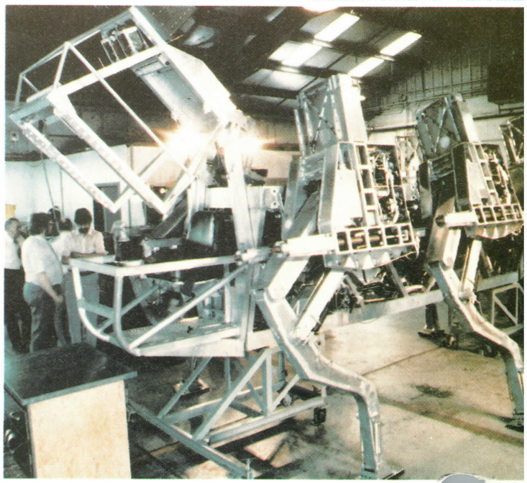
Unmanned planetary exploration vehicles are built up from separate modules so they can travel over very rough surfaces and not be upset. They analyse samples and send the results back to Earth by radio.



NASA

Ground effect machines, usually known as hovercraft, can cross almost any terrain because they are supported on a cushion of air. In this case it is retained by an inflatable rubber skirt right around the perimeter.

The American ASV (Adaptive suspension Vehicle) has a maximum speed of 5 km/h over rough ground.



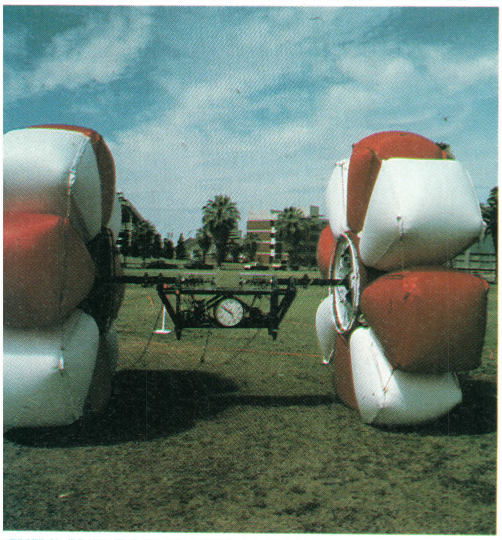
DOD

Dune buggies are home-made leisure vehicles for use among the empty sand dunes of southern California. Big tyres and a powerful engine are essential.

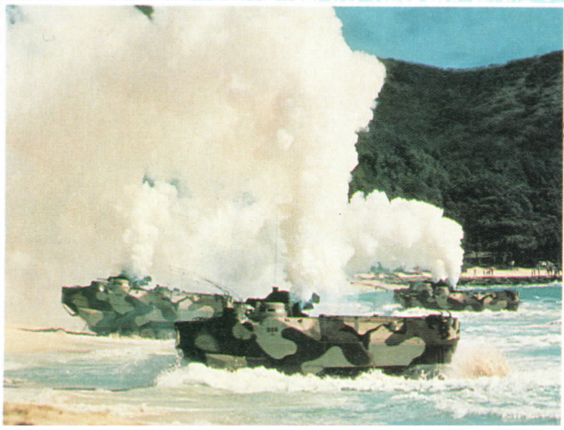
Mary Fisher/Colorific!

Yamaha Motor Canada

Mars Ball has a system of gas bags that inflate and deflate in sequence; this propels the vehicle slowly across the planet's surface.



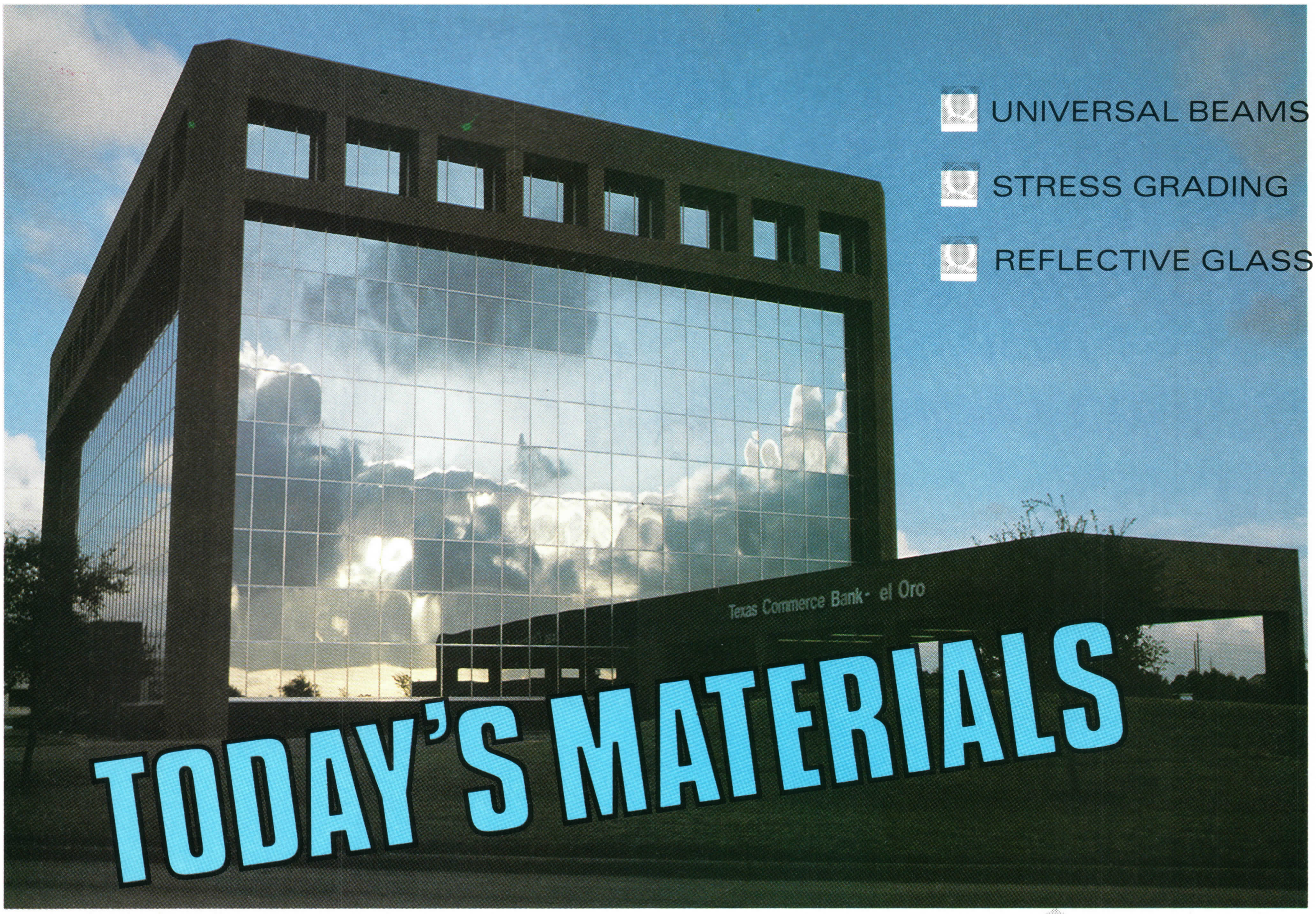
Lori Stiles, University of Arizona



DOD

Snowmobiles fitted with skis and powered by a motorcycle engine can reach up to 50 km/h. Some versions are used for polar exploration.

Amphibious landing craft are now equipped with a small cannon to suppress defensive fire, and smoke generators to conceal movement up the beach.



Spectrum Colour Library

THE CORRECT CHOICE OF materials for each part of a structure is one of the most important jobs that architects and engineers do during the design phase of any project.

Cement is the universal building material because it can do many different jobs, depending on the way it is mixed. It can be used as

- a weak mixture of sand and cement for laying bricks and lightweight blocks
- a strong mixture of sand and cement with silicon additive for making a waterproof layer inside or outside buildings
- a mixture of sand, cement and gravel making a weak concrete suitable for floor slabs and foundations
- a mixture of sand, cement, stones and detergent for making full strength structural concrete.

Bricks are made from clay that is shaped in a mould, then fired in a kiln. Thousands of different types of brick are produced, mainly because the colour and quality of the clay used to make them varies according to the clay pit it is dug from.

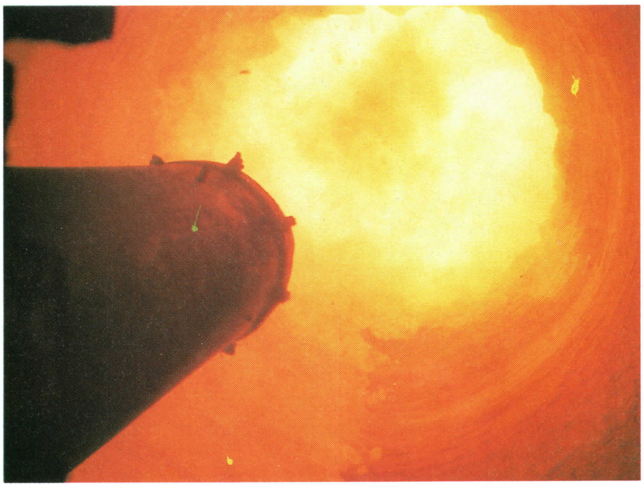
The cheapest bricks are known as Flettons and are normally made from Oxford clay. This type of clay contains a certain amount of carbon. The brick kiln is filled with newly-moulded bricks, then heated by gas. Half way through the process, a temperature is reached that starts the carbon in the clay itself burning. From then on, the gas to the kiln can be turned off and the carbon acts as the 'fuel' for the rest of the process. Unfortunately, flettons have an ugly, burnt look, so they are only used where they will not affect the final appearance of the building.

***Mirrored glass** is fitted to air conditioned buildings to keep the sun out. This prevents heat building up and overloading the air conditioning.*

The visible part of most small buildings is built from facing bricks. The best facing bricks are made from solid clay in a traditional kiln, which gives them an attractive rich colour. Cheaper facing bricks are now made much like flettons, but their sides and edges are covered with sand which is fused into the clay at a high temperature. These sand-faced bricks do not look as handsome as traditional bricks but they are much cheaper.

Re-cycled ash

All modern houses must have insulated walls and brick is a good conductor of heat, so it is a bad

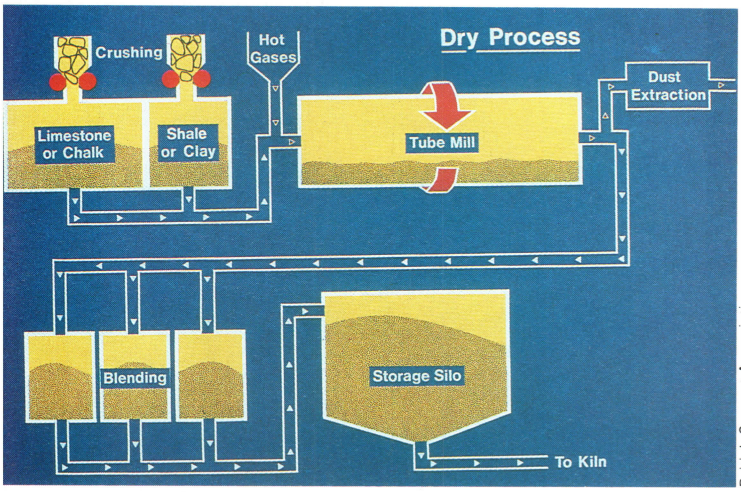


British Cement Association

***Cement kilns** are tilted at 20 degrees to the horizontal. Raw materials are fed in at one end and the kiln revolves slowly, tumbling them through the hot zone where the temperature reaches 1400°C. Clinker (ash) is removed at the other end, then ground into a fine powder ready for use.*

THE UNIVERSAL BEAM

Universal beams are so called because of the huge variety of jobs that they can be used for. Looked at from one end, the beam is 'I' shaped: the central vertical piece of steel is called the web, while the horizontal cross pieces are known as flanges. When used to support a wall or a ceiling the weight 'sits' on the flange, but the deep web supplies most of the strength. If really heavy weights are to be supported, a beam with a web that is three times the size of the flanges is generally used.



British Cement Association

***Cement plants** are built close to the quarries that supply their raw materials. In the modern 'Dry Process', the raw materials are crushed, dried with the exhaust gases of the kiln, then fed into a tube mill; here they are powdered ready to be mixed to a set chemical composition before being loaded into the kiln.*

insulator. So in most houses and many other buildings, the inner part of the outer walls is made from lightweight insulating blocks. Ten or twenty times larger than bricks, these are much cheaper to buy and can be laid much more quickly. The building blocks are made from cement mixed with the ash from coal-fired power stations – a good way of re-cycling spent materials – and are light grey or blue in colour. As they are not waterproof, they are not at all suitable for the outside of buildings.

All types of concrete are made by mixing sand and stone with cement and water to form a 'porridge'. The cement acts as a hardening agent. The initial strength is developed in the first week, but concrete goes on getting stronger over the next 40 years.

Experiments have been undertaken with 'high alumina' concrete which sets very quickly and reaches maximum strength in a matter of days. Unfortunately, the alumina remains active after the concrete has set and reacts with the silica in the concrete. This can weaken beams and cause them to collapse. Research is continuing, with the main object of combining the advantages of high alumina and conventional concrete.

Structural steel is made in many different shapes and sizes, but the best-known form is the girder or Rolled Steel Joist (RSJ) – officially known as a Universal Beam. These make up the basic structure and supply all the strength in steel-framed buildings. Concrete is used for the floor slab at ground level and to form the ceilings. Unless reinforced, it does not contribute any strength. Universal beams are also used to build pre-fabricated structures, such as out-of-town supermarkets, and large installations including aircraft hangers.

Girders may be joined together with large bolts, or they can be welded. A welded joint is made by passing a strong electric current down an iron rod so that the steel of the girder and the welding rod both melt. The molten metal forms a pool and, when the weld is correctly made, the crystalline structure of the metal reforms when the joint cools. This makes a very strong joint that extends the whole depth of the metal. Because a basic steel frame can be erected much more quickly than a concrete one, more steel-framed buildings are being built than re-inforced concrete ones.

Natural materials

Timber is the only building material that grows rather than being dug out of the ground. It is a renewable resource – and very cheap compared with other structural materials such as steel. Timber is also very easy to cut and shape using simple tools; in addition it can be carved and sculpted without seriously affecting its structural properties.

Wood was probably the first building material used by mankind, but it still competes very successfully against modern manufactured products. It can do so because the timber producers have developed a

British Steel

Tony Stone Photo Library, London

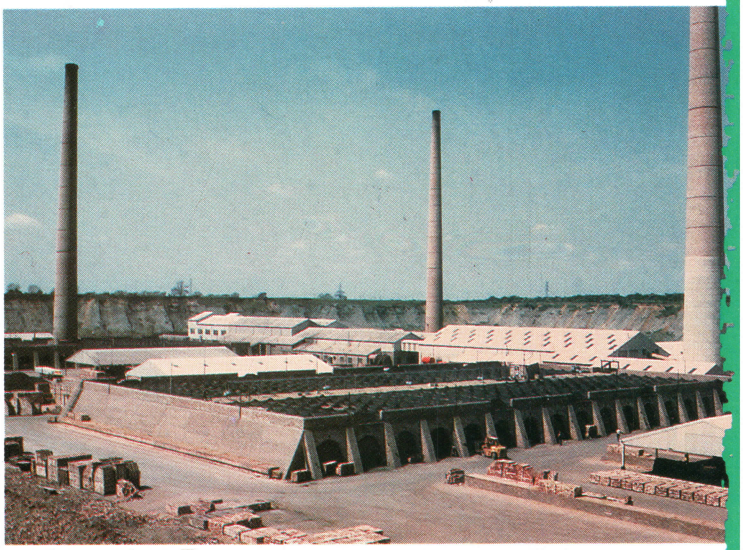
***Concrete** is a mixture of cement, water and stones, plus a detergent to make it easier to lay. Concrete is usually mixed at a specialist plant (where the materials can be carefully measured out), then delivered by a mixer lorry, poured into position and spread by hand or machine. Samples taken from each batch are tested for strength at a laboratory.*

***Structural steel** is made in a large number of different sections; I-shaped girders (or Universal beams) are the most common. They are produced by passing hot steel through a pair of rollers powered by electric motors. Each roller has a special profile which shapes the steel.*

George Wimpey PLC

***Structural steel** can now be rolled into circles and curves, without sacrificing strength, using a special grade of steel that does not crack during the bending process. This type of structure is usually covered with curved glass and looks like a giant conservatory.*

***Hoffmann kilns** are used to bake London bricks, (or Flettons, as they are also called). The bricks are moulded by machine and taken through the kiln on a continuous conveyor. The kiln can be fired for weeks before the fireproof lining has to be renewed.*



London Brick Company

variety of treatments for raw timber from the forest. Instead of simply using chunks of rough timber, wood is now processed into a variety of products that give guaranteed performance and have a long life in the same way as any other modern material.

The commonest structural timbers are the joists that support floors and ceilings, and the rafters that support roofs in small and medium – sized houses. When logs have been converted into useable sizes and grades of timber at the sawmill, the strength of each piece is tested on a hydraulic machine. If the length of timber does not break when the load is applied, it is labelled to show that it has been 'stress-graded'. Architects can then rely on it to support a certain weight without snapping.

Brick Development Association

***Semi-engineering bricks** are hard and waterproof. They are used underground, or to support an extra-heavy load. The holes get filled with cement during laying, giving extra sticking power.*

Steam presses

Composite materials built up from artificial fibres are now very common. Plywood was the first product of this type. It is built up from thin layers of wood which are glued together in giant, steam-heated presses. The sheets are laid so that the fibres of wood in adjoining sheets run at right angles to each other. This produces a material of enormous strength that can be used either on its own or to reinforce other forms of timber at points of stress as in timber-framed houses, for example.

Two different types of timber are used in construction – softwood and hardwood. Softwood is liable to rot and to be eaten by insects, so it is nearly always treated with preservatives. This can be done

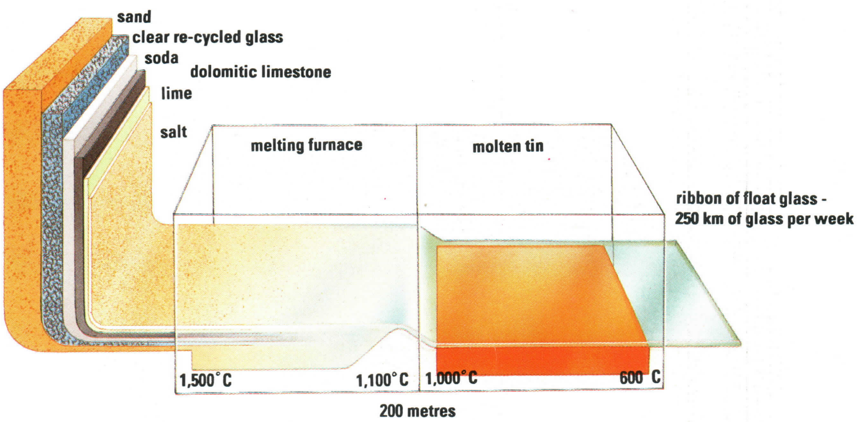
***Float glass** is made in the normal way, but at 1000°C the glass is floated on top of a 'bath' of molten tin. It comes off the end of the bath in a continuous ribbon, then passes into the cooling area.*

Just amazing!

FINER THAN DUST

IN EVERY KG OF CEMENT, THERE ARE 50 MILLION MILLION SEPARATE PARTICLES. THE SURFACE AREA IN ONE 50 KG BAG TOTALS 17,500 SQUARE METRES – ROUGHLY FOUR FOOTBALL PITCHES.

Paul Raymonde



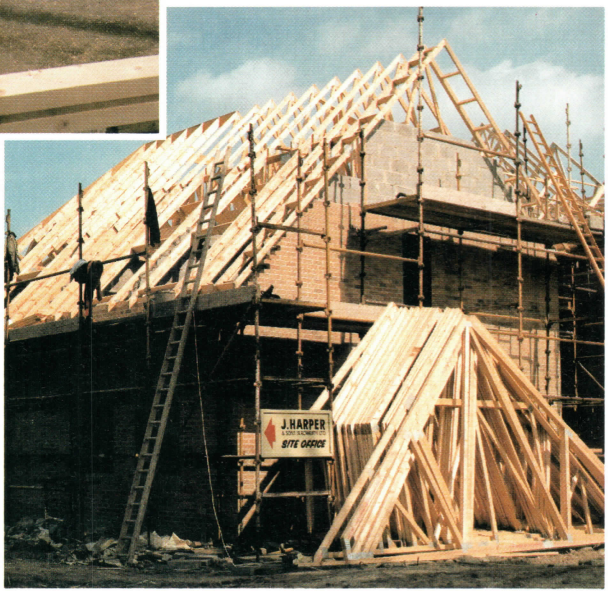
GLASS IS SUPERCOOL

Glass is made by melting sand, washing soda and other minerals in a furnace at around 1000°C. When it cools down, glass does not solidify in the same way as most materials. Instead, it acts as a 'supercooled' liquid: it appears solid, but behaves like a liquid. This shows up in old glass windows – the glass flows very slowly to the bottom of the pane, forming perceptible ripples that distort the view.

Pilkington Glass Ltd

The float glass cooling area *is a long set of temperature-controlled rollers. This controlled cooling process takes about 30 minutes and is very important because it takes out the stresses that are set up in the glass during the manufacturing process. Computers instruct cutting machines on how to cut the cooled glass to avoid any waste.*

Graham Moore/Hickson Publicity



Graham Moore/Hickson Publicity

Roof timbers *are computer-designed and factory-assembled into roof trusses. As thin timber is used, the joints are re-inforced with plywood or steel spreader plates. On site (right), the trusses are lifted into place with cranes and a complete roof can be fixed in a day.*

after the wood has been used, but the chemicals involved are unpleasant and it is sometimes impossible to ensure full coverage.

Better coverage can be obtained by enclosing the timber in a vacuum chamber, and then applying the preservative which will penetrate every cell. Wood treated in this way is guaranteed to last at least 60 years when used according to instructions.

Now that the main strength of many buildings is provided by a steel or concrete frame, materials that fill the gaps between the structural elements do not have to take any weight. Bricks are often chosen as the filler because they are cheap and they give a traditional appearance to a high technology structure. Factory-made cladding is preferred when the architect wants a hi-tech look.

Thin panels of steel or aluminium, coated with epoxy paint at the factory, are a cheap and long lasting form of cladding that can be quickly fixed to the framework. Another cladding system uses sheets of reconstituted marble that look very natural, even though the sheets are made in a factory. However, plate glass is probably the cheapest and longest-lasting cladding.

Glass cladding

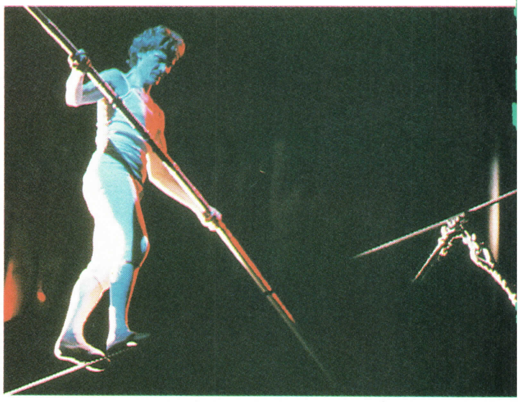
Glass used for cladding is plate glass quality – almost perfectly flat on both sides and both sides are also exactly parallel, so there is very little optical distortion.

The float glass process can also be used to process normal, clear glass into a variety of other types. The best known of these is reflective, or solar control, glass. The mirrored outer surface of the glass reflects the sun's rays, preventing a build-up of heat inside. However, it doesn't prevent the occupants of the building from seeing through the windows as normal.

Traditional Japanese *houses have a wooden structure. The walls may also be made of wood, but reeds are often preferred because they give insulation against the cold. The windows are filled with oiled paper, not glass. Inside the house, sliding partitions are used instead of fixed walls so that the living area can be divided up into bedrooms at night.*

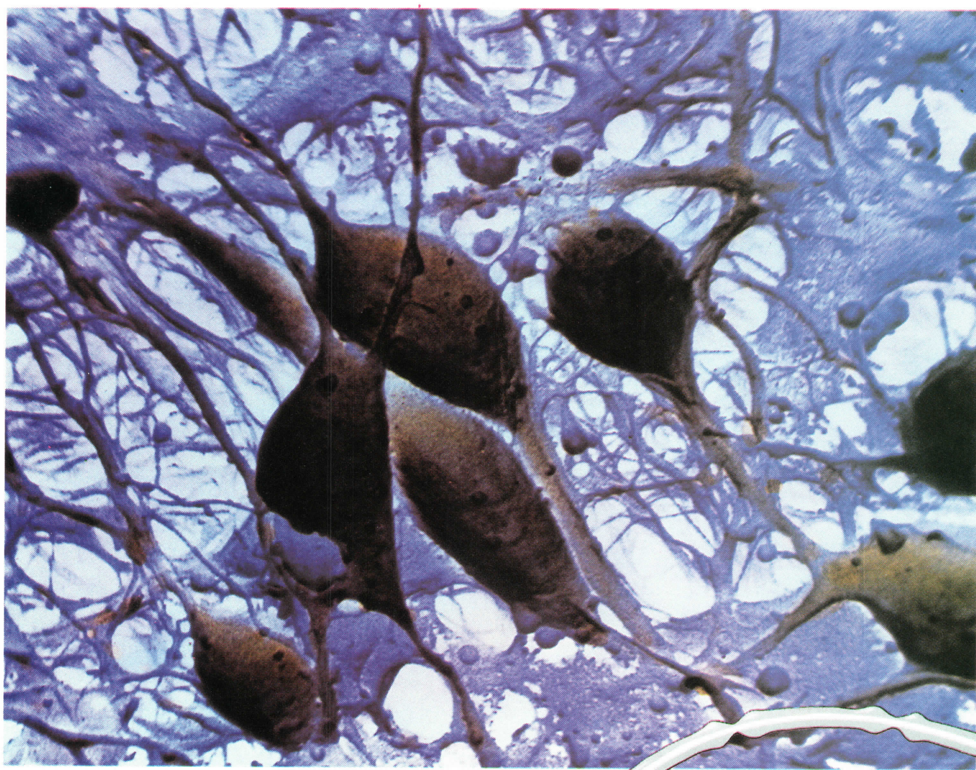
Japanese National Tourist Organization

MIND AND BODY



Giovanni Rufino/Dot/Colorific!

Special areas of the brain automatically control skills such as balance, leaving other areas free to carry out conscious actions.

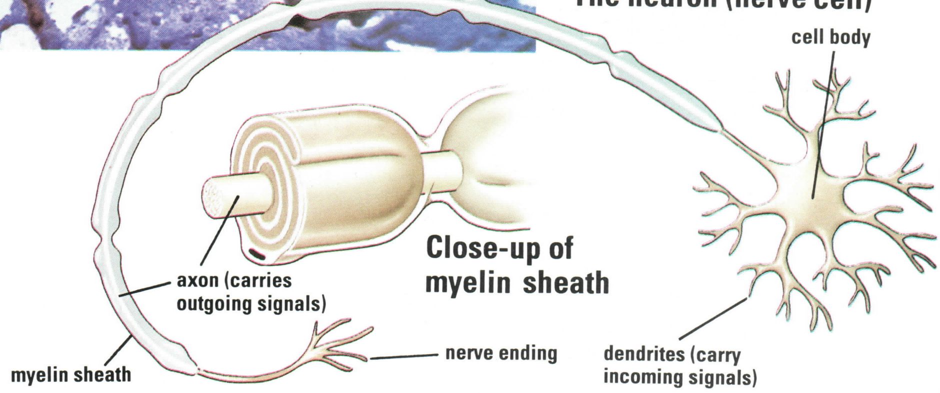


CNRI/SPL

Nerve cells (neurons) carry electrical signals. Some take messages from sense organs, such as the tongue or eye, and pass them to the brain or spinal cord. Others pass messages from the brain or spinal cord to muscles and glands. Each cell has a rounded body with many fine fibres, plus a single long fibre, called the axon.

Axons carry signals away from the body of the neuron to the fine fibres (dendrites) of other nerve cells. Axons with a fatty coat of myelin transmit impulses faster than those without one.

The neuron (nerve cell)



NERVOUS SYSTEMS

REFLEX ACTIONS

BRAIN STRUCTURE

THE DOMINANT POSITION OF the human race on the Earth is due entirely to its highly developed brain. The brain consists of a mass of specialized nerve cells (or neurons) together with many other cells that support and nourish the neurons. The brain is thus a major part of the nervous system – a communication network that links all parts of the body.

The nervous system has two main parts. The central nervous system (CNS) consists of the brain and the spinal cord. The peripheral nervous system (PNS) includes all the nerves running to and from the CNS.

The fundamental unit of the nervous system is the neuron. It is generally believed that all the neurons in the CNS are present at birth and grow as the infant grows. Unlike most cells in the body, neurons do not reproduce themselves and, once lost through injury or disease, are gone forever.

A typical neuron has three parts. The *cell body* makes the chemicals needed for the neuron's working. Short fibres known as *dendrites* extend from the cell body. They carry nerve impulses towards the cell body. A very long extension of the cell, the *axon*, carriers the nerve impulse away from the cell body and on to other neurons.

In one type of nerve the axon is encased in a fatty sheath made of a substance called myelin. Nerve impulses are conducted very quickly along these axons – at speeds of up to 400 km/h. Impulses travel more slowly along nerve fibres that do not have myelin sheaths.

At its far end, the axon divides into branches, each ending in a number of tiny knobs. Each knob is very close to, but not actually touching, a dendrite from another neuron. This gap is called a synapse, and messages are transmitted across it.

Nerve fibres are of two major

types: *motor fibres*, which carry impulses from the central nervous system to muscles; and *sensory fibres*, which carry impulses from sense organs, such as the taste buds in the tongue, to the CNS.

The main parts of the peripheral nervous system are *nerves*, which connect the central nervous system to all other parts of the body, and *ganglia* – groups of nerve cells located at various points. A nerve is a bundle of motor and sensory fibres, together with other tissue and blood vessels. There are 43 pairs of major nerves: 12 pairs emerge from the underside of the brain (the cranial nerves) and 31 pairs from the spinal cord (spinal nerves).

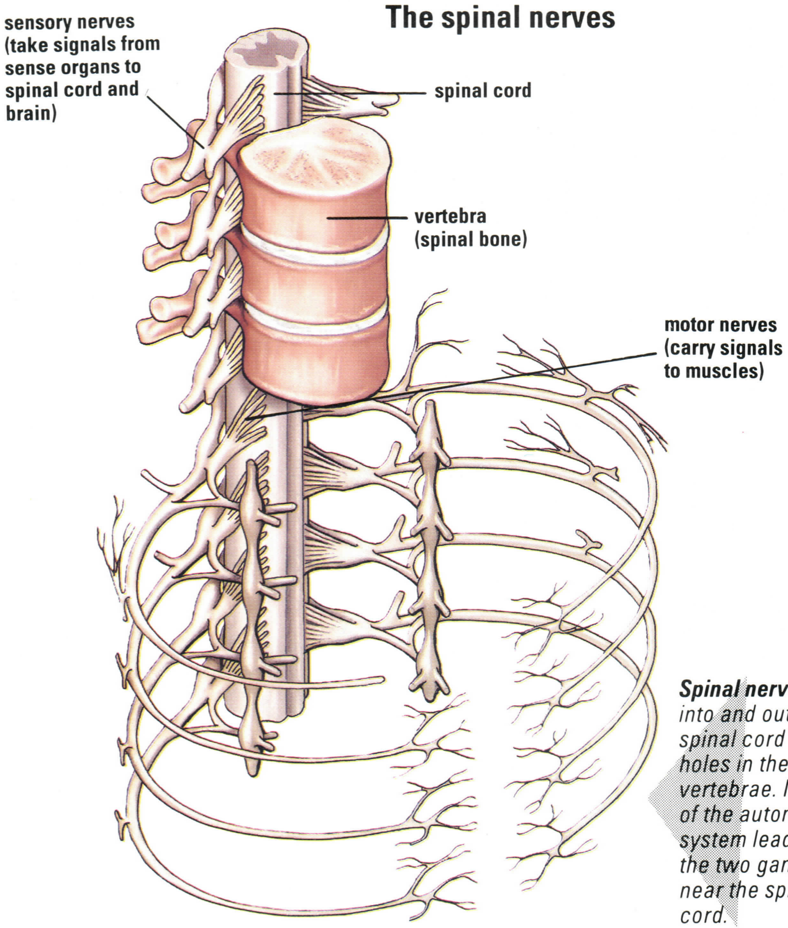
The cranial nerves mainly go to sense organs and muscles in the head. But one very important cranial nerve, called the vagus, goes to the digestive organs, to the heart and to air passages in the lungs.

Some cranial nerves, such as the

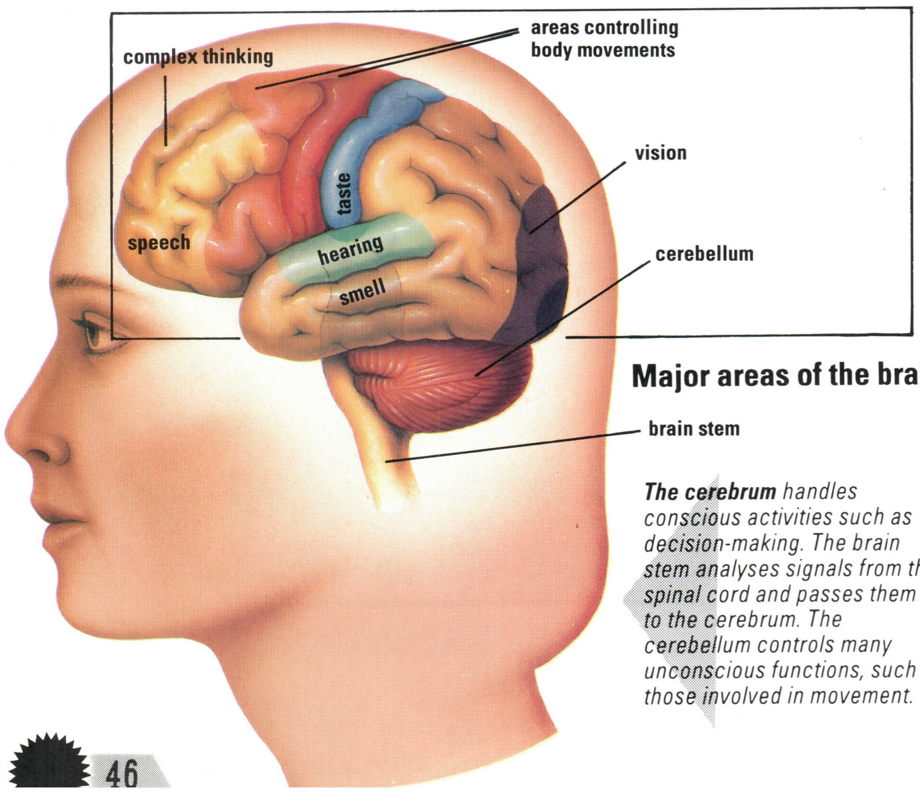
***Reflexes** such as the knee-jerk response are controlled by the spinal cord. Good responses show the nerves are working well.*

Jerry Mason/SPL

The spinal nerves



***Spinal nerves** pass into and out of the spinal cord through holes in the vertebrae. Nerves of the autonomic system lead from the two ganglia near the spinal cord.*



Major areas of the brain

***The cerebrum** handles conscious activities such as decision-making. The brain stem analyses signals from the spinal cord and passes them up to the cerebrum. The cerebellum controls many unconscious functions, such as those involved in movement.*

BRAINWAVES

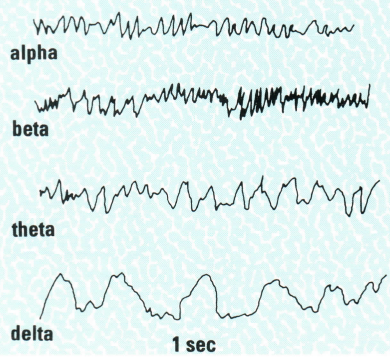
The rhythmic electrical voltages produced by the brain are measured with an electroencephalograph (EEG). They provide clues to the brain's activity. If they are too fast or too slow, there is something wrong with the subject's brain.

Alpha waves about 10-12 cycles per second. They dominate the brainwaves when the person is relaxed. They disappear during sleep.

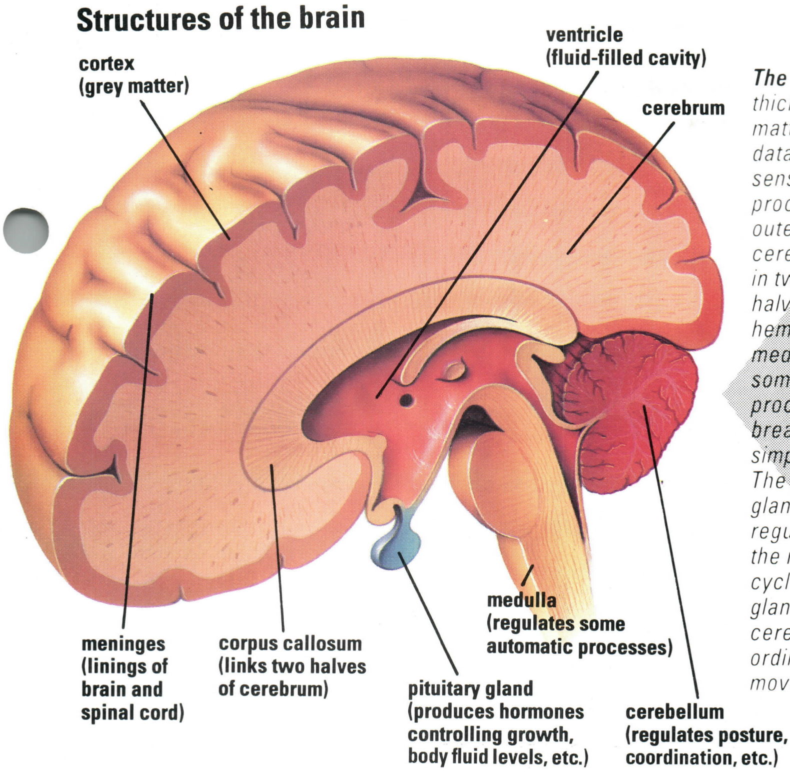
Beta waves 15-60 cycles per second. They appear when the person is sedated.

Theta waves 5-8 cycles per second. They occur during drowsiness and in light sleep, replacing alpha waves.

Delta waves 1-5 cycles per second. These large waves occur during deep sleep in adults, but all the time in infants.



Structures of the brain



The cortex, *a 3 mm thick layer of 'grey matter', is where data from the senses is processed. It is the outer 'skin' of the cerebrum, which is in two linked halves, or hemispheres. The medulla regulates some automatic processes, such as breathing and simple reflexes. The pituitary gland's hormones regulate growth, the reproductive cycle and other glands, while the cerebellum co-ordinates movements.*

A stroke victim *gradually regains his reflexes through gentle exercise. Strokes are due to a failure of the brain's blood supply.*

Josephus Daniels/SPL

optic nerve to the eye, contain only sensory fibres. But the spinal nerves always contain both motor fibres and sensory fibres.

A short distance from the spinal cord each spinal nerve splits into branches, which in turn split into numerous smaller ones, forming a network radiating all over the body.

The peripheral nervous system has two main divisions: the *somatic* nervous system, which is under our conscious control, and the *autonomic* system, which is under unconscious control.

The somatic system collects information about the outside world from sensory organs, such as the eyes, which contain special receptor cells. It transmits signals along motor fibres from the central nervous system to the muscles, so that we can carry out movements of our bodies.

The autonomic system is mainly concerned with keeping up the automatic functions of organs such as the heart, lungs, stomach, intestine, bladder, sex organs and blood vessels, without deliberate mental or other effort on our part. It consists entirely of motor nerves arranged in relays from the spinal cord to the various muscles.

Sympathetic systems

The autonomic nervous system has two parts, known as the *sympathetic* and *parasympathetic* systems. They have different effects on the organs they serve. For example, parasympathetic nerves make the airways leading to and from the lungs constrict (grow narrow). The sympathetic nerves serving the same areas cause the airways to widen. In general, the sympathetic system arouses bodily organs, preparing them for 'fight or flight'. The parasympathetic system has the opposite effects on those organs.

The whole of the autonomic system is controlled by an area of the brain called hypothalamus. This receives information about any variations in, for instance, the body's chemical make-up and adjusts the autonomic system to bring the body back to the right balance. For example, if oxygen in the tissues is used up during exercise, the hypothalamus instructs the autonomic nervous system to increase the heart rate in order to supply more oxygenated blood.

The peripheral nervous system relays sensory and motor messages between the central nervous system and the body's muscles, glands and sense organs. It does not analyse sensory signals or initiate motor signals. Both these activities, and much else besides, occur in the central nervous system – the brain and spinal cord.

The spinal cord is a roughly cylindrical column of nerve tissues, about 40 cm long in an adult, that runs inside the backbone from the brain to the lower back. It contains *descending* nerves, which send motor impulses from the brain to the peripheral nervous system, and *ascending* nerves, which channel sensory impulses to the brain.

Reflex movements

Nerve fibres extend in long bundles from parts of the brain. They run varying distances down the spinal cord. At the ends farthest from the brain they come into contact with the fibres or cell bodies of sensory and motor neurons belonging to the peripheral nervous system. Messages can be transmitted across the synapses, between the peripheral neurons and the spinal neurons.

The spinal cord controls simple reflex actions. This is achieved by neurons whose fibres extend short distances up and down the spinal cord, and by interneurons, which relay messages directly between the sensory and motor neurons.

If, for example, you accidentally put your hand on a hot stove, pain receptors in the skin send messages along sensory fibres to the spinal cord. Some of these messages are relayed immediately by neurons to motor neurons that control the movements of the arms and hand muscles, so the hand is quickly – and automatically – withdrawn. Other messages travel up the spinal cord and are relayed by interneurons to the motor neurons that control the neck's movements. As a result, the head is automatically

Just amazing!

BIG-HEAD!

DURING THE AVERAGE PERSON'S LIFETIME THE NEURON NETWORK IN HIS OR HER BRAIN WILL STORE ABOUT 1,000 MILLION MILLION BITS OF INFORMATION.

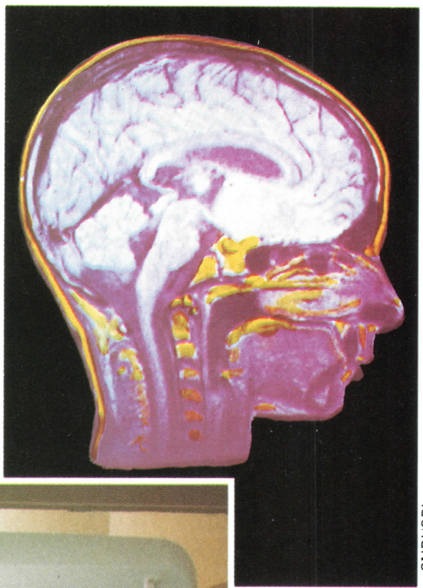
Paul Raymonde

turned towards the source of the pain. Further messages are carried all the way up to the brain, where they cause the conscious sensations of heat and pain.

The brain

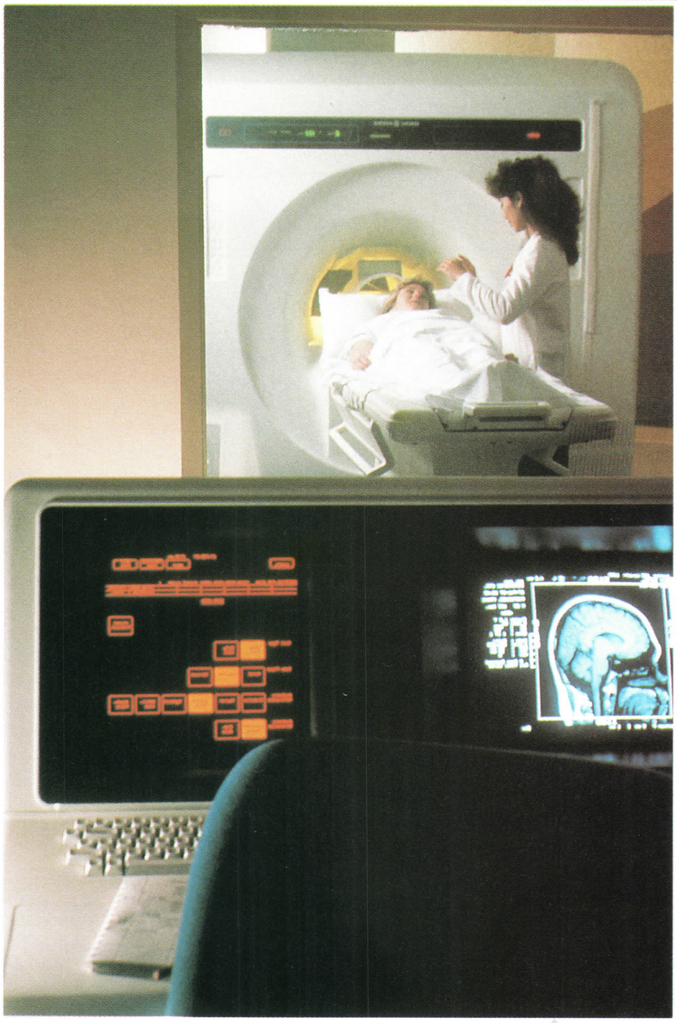
Basically the brain can be divided into three different regions; hindbrain, midbrain and forebrain. Each of these regions is in turn divided into separate areas.

The cerebellum is the largest structure in the hindbrain. It is the area that is mainly concerned with motor activities. It sends out signals that produce movements in muscles so that posture and balance are



CNRI/SPL

The living brain *can be revealed by the technique of NMR (nuclear magnetic resonance). This image of a child's brain clearly shows the folds of the cortex, the spinal cord and the cerebellum (lower rear of the brain).*



ZEFA

An NMR scanner *surrounds the head of the patient. A pulsed magnetic field causes atoms in body tissues to send out radio waves. A computer builds the signals into an image.*

maintained. It also works with the motor areas of the cerebrum to co-ordinate movements.

The brain stem links the brain with the spinal cord. It comprises part of the hindbrain, all of the midbrain and part of the forebrain. It is here that all incoming and outgoing messages come together and cross over (the left side of the body is governed by the right-hand side of the brain and vice versa).

The various structures in the brain stem, including the medulla and the reticular activating system, control heart rate, blood pressure, swallowing, coughing, breathing and unconsciousness.

The hypothalamus is concerned with the control of vital functions such as eating, sleeping and temperature control. It lies at the base of the brain, under the cerebrum. It is immediately below the thalamus, which acts as a telephone exchange between the spinal cord and the cerebrum.

The cerebrum is the largest part of the forebrain. It is more developed in humans than in any other animal and is essential for thought, memory, consciousness and complex thought processes. This is where the other parts of the brain send incoming messages for a decision. It is divided into two halves, called 'hemispheres'. Each specializes in certain tasks. Usually the left hemisphere deals with language, while the right handles musical and artistic activity.

The basal ganglia lie at the centre of the cerebral hemispheres. They are a mass of 'grey matter', which is mostly made up of nerve cell bodies. These cells form a complex control system that co-ordinates muscle activity and allows a person to perform specific types of movement without conscious thought.

The cerebral cortex is the wrinkled layer of grey matter, 3 mm thick, folded over the outside of the cerebrum. This part of the brain has become so highly developed in humans that it has had to fold over and over in order to fit inside the skull. Unfolded, it would cover an area 30 times as large.

National Anti-Vivisection Society

Medicines *are tested on animals before they are used for humans. A tube has been fitted into this monkey's skull so drugs can be passed into its brain.*